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THE PHOMOPSIS DISEASE OF EGGPLANT AND ITS CONTROL

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EIGHT PLATES AND TWO TEXT FIGURES

Heretofore the only serious fruit trouble of eggplant (*Solanum melongena L.*) known in the Philippines was the Phytophthora disease, caused by *Phytophthora melongenae* Sawada, which was reported by Ocfemia(6) in 1925. The anthracnose disease due to a species of *Gloeosporium* was sometimes observed on the fruits of eggplants during rainy or humid days, but there was no instance in which its occurrence occasioned a serious loss of crop. September 10, 1935, the Bureau of Plant Industry received a complaint from a grower in Tanag, Arayat, Pampanga Province, about a serious fruit-rot disease of eggplant (Native Long Purple variety) which destroyed in transit 10 per cent of the first harvest and 20 per cent of the second. Owing to the greater seriousness of the disease in the more mature stages of the plants, a higher rot infection of the fruits was noted in later studies in the same field. In an examination of the field, September 11, 1935, 37 per cent of the fruits were found with the disease. Three weeks later, October 1, 1935, 64 per cent of the fruits in the same field were recorded as showing rot infection of various stages. All of the 7,000 plants in that field showed leaf spots which were found later to be due to the same organism that caused the rotting of the fruits. About 50 per cent of the plants were observed to be heavily

The plants attacked by the disease on the stem show signs of rapid weakening. The leaves and fruits that develop on plants showing the disease on the stems are usually smaller in size than those produced by the healthy plants. As soon as the lesions have encircled the stems by spreading laterally the foliar parts above the point of infection wilt and dry up. The entire plant may wilt and die when the lesion has girdled the main stem. The shrinking of the tissues at the points of infection, especially on parts of the stems where the woody tissues are not strong, usually causes the falling-over or tipping-over of the foliar parts above the point of infection. Toppling over of the foliar parts was not observed on plants attacked by the disease on parts of the stem if the latter was strong and woody.

The pycnidia of the fungus develop on the old lesions (Plate 2, fig. 4). These minute, black bodies are seldom produced in abundance on the stem lesions. The bark within the lesions where many of these black bodies are found sometimes cracks and sloughs off.

ON THE LEAVES

The Phomopsis disease is frequently serious on the leaves. In fact, it is frequently observed to be more prominent on the leaves than on the stems during the earlier stages of the egg-plant in the field. It manifests itself in the form of spots (Plate 1, fig. 2) which are shown more conspicuously on the older than on the younger upper leaves. The first visible evidence of infection on the leaves is in the form of small, more or less circular, buffy olive (R) spots which usually develop within 10 days after the causal fungus has entered and established itself in the tissues. Under favorable environmental conditions this period may be shortened to about six days.

The small incipient spots which mark the points of infection later develop into definite cinnamon-buff (R) lesions with irregular blackish brown (R) margins. The old spots vary from 4 to more than 20 millimeters in diameter. When obstructed by the veins and when formed along the margin of the leaf, the spots become more irregular in shape. They tend to converge into large dead areas which sometimes cover a great portion of the leaf blade. A lesion formed at the petiole or on the lower part of the midrib often causes the death of the entire leaf. The blight symptoms which may be observed on some leaves are often a result of the coalescence and rapid spread of lesions

which occur under humid conditions. One to four lesions formed on the leaf blade do not usually change much the appearance of the leaf, but five or more large lesions were frequently observed to be sufficient to cause yellowing or premature dropping away of the leaf in about a week.

The pycnidia of the causal fungus are produced on the dead tissues of the lesions (Plate 1, fig. 3). They may be found on both surfaces of the leaf, but they are usually produced more abundantly on the upper than on the lower surface. If the spot encloses a part of the larger vein of the leaf the pycnidia are formed mostly on the depressions on the vein.

ON THE FRUIT

The Phomopsis disease attacks the fruit in all stages of its development. On the fruit (Native Long Purple variety) the disease appears first as minute, sunken, dull dusky purple (R) spots. Oftentimes the dull dusky purple color is absent, in which case the spot appears as minute, soft depressions on the fruit. During the humid days following a rainy period, numerous spots develop on some fruits of plants which showed previously a severe infection of the disease on the leaves. With age the spots merge and form large rotted areas (Plate 3, fig. 1). The old lesions appear as buffy brown, (R) circular, oblong or irregular depressions which are usually large when they are few and much reduced in size when they are numerous. Once established on the fruit, the disease continues to develop until the entire fruit rots. While in its incipient stage the progress of the disease may be inhibited temporarily by unfavorable weather conditions, but as soon as conditions become favorable it resumes its activity and continues to cause the fruit to rot. During moist or rainy days the diseased fruits rot rapidly, drop off and disintegrate. Under dry weather conditions the diseased fruits shrivel up rapidly and mummify as hard black objects (Plate 3, fig. 3). The disease on the fruit sometimes start on the peduncle and calyx lobe. When the stem-end tissues die as a result of an infection on either the calyx lobe or the lower part of the peduncle, the fruit may drop off from the calyx lobe.

Numerous pycnidia (Plate 3, fig. 2) develop on the rotting parts of the fruits when the disease is in its advanced stage. If rotting is allowed to continue the entire fruit may later be found heavily studded with the pycnidia of the fungus.

ON THE SEED

Seeds from badly diseased fruits may be differentiated from healthy seeds by a pallid purplish gray (R) tint. Lightly infected seeds appear normal, but when planted most of them do not germinate.

THE CAUSAL ORGANISM

ISOLATION AND PREPARATION OF SUBCULTURES

The causal fungus was isolated by the spore dilution method as follows: Several pycnidia of the fungus were scraped off from the lesions and crushed in test tubes of sterile water to release the spores from the pycnidia. The clouding of the water in the test tubes indicated that innumerable spores were suspended in the liquid. Five or more loopfuls of the suspension were transferred into the test tubes of melted agar which was cooled down to about 40° C. Further dilution was made by loop transfers from the melted agar into other tubes of melted agar. Two drops of 25 per cent lactic acid was added into each test tube of the agar to prevent the growth of bacterial contaminants. The tubes were shaken and their contents poured into sterile Petri dishes. After 6 days of incubation at room temperature the stock cultures were made by transferring bits of the mycelial growth from a single and most isolated colony into test tubes of steamed eggplant stems. The subcultures used in subsequent studies were made by inoculating the medium with a loopful of the spore suspension which was prepared by crushing in a tube of sterile water the pycnidia that developed in stock cultures.

CULTURAL CHARACTERS

Petri dish cultures.—The fungus was studied on the following media: potato-glucose agar, oatmeal agar, cornmeal agar, prune agar, Leonian's malt extract agar,[2] papaya agar, string bean agar, cucumber seed agar, eggplant decoction agar, steamed rice, and steamed cornmeal. The cultures were incubated in a closed chamber at room temperature.

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[2] Bonar's modification of Leonian's agar:

Medium:

Dihydrogen potassium phosphate	1.2 g.
Magnesium sulphate	0.6 g.
Peptone	0.6 g.
Maltose	6.0 g.
Malt extract	6.0 g.
Distilled water	1,000 cc.
Agar	1.5–2.0%

The growth on all the agar media was white, distinctly lobed at edges of colonies, and in some cases distinctly zonate (Plate 4, fig. 1). While the growth was flat in general, aërial tufts of hyphae were usually produced on papaya agar and potato-glucose agar (Plate 4, fig. 1, *c* and *h*). These two media were also found to be the best agar media for mycelial growth but not for fruiting. For the production of fruiting structures known as pycnidia, oatmeal agar (Plate 4, fig. 2, *a*), prune agar, Leonian's malt extract agar, and eggplant decoction agar (Plate 4, fig. 2, *b*) proved to be fairly good, although the mycelial growth was not as profuse on these media as on potato-glucose agar and papaya agar. Fair growth was shown by the fungus on string bean agar, but few pycnidia were produced on this medium. Rather poor mycelial development and scant production of pycnidia were shown by the fungus on cornmeal agar and cucumber-seed agar. Smaller pycnidia were also produced on these two media. Of all the media tried, steamed cornmeal and steamed rice were found to be most favorable for both mycelial development and fructification. The pycnidia, which were either submerged or superficial, were produced within nine days on all media used.

Tube cultures.—Practically the same type and volume of mycelial growth as in Petri dish cultures were produced by the fungus in test tube cultures on the same agar media. However, the zonate formation of the mycelial growth was either absent or indistinct while the lobed character of the growth was clearly shown only on prune agar, eggplant agar, Leonian's malt extract agar, and string bean agar. The pycnidia develop on all agar media tested, but they are usually produced in moderate amounts on prune agar (Plate 4, fig. 3, *a*), eggplant agar (Plate 4, fig. 3, *b*), oatmeal agar (Plate 4, fig. 3, *c*), and Leonian's malt extract agar. Numerous pycnidia were produced by the fungus on steamed eggplant stems and fruits, and steamed string beans. Mature pycnidia sometimes extrude yellowish masses of spores.

MORPHOLOGIC CHARACTERS

Mycelium.—The mycelium consists of fine, hyaline, septate hyphae which ramify within the diseased parts of the host tissues. The hyphae vary from 1.5 to 3.3 μ in diameter. In artificial cultures some of the hyphal threads may grow as large as 4.2 μ in diameter.

Pycnidia.—The pycnidia are the minute black pustules that develop on the old lesions. They are at first formed within the

host tissues, but as they grow in size, they break through the epidermis and expose the parts which bear the ostioles. The pycnidia are generally subglobose (Plate 5, fig. 1), some may be nearly lenticular or flask-shaped and others irregular. Irregular and beaked pycnidia are found more often on stems than on the leaves and fruits. The beaks vary from short knobs to well-defined protuberances which may reach a length of 76.0 μ. In cultures on steamed string beans and on prune agar, pycnidia with beaks about 1,500 μ long are occasionally met with.

TABLE 1.—*Measurements of the pycnidia obtained from the different parts of the diseased eggplant*

Origin of the pycnidia.	No. measured.	Height.		Width.	
		Range.	Average.	Range.	Average.
		microns	*microns*	*microns*	*microns*
Leaves	75	76.0–144.0	98.8	72.0–162.0	111.0
Stems	50	91.0–304.0	184.0	114.0–292.0	185.0
Fruits	100	94.2–298.3	193.3	110.0–345.4	221.1

A considerable variation in size of pycnidia was also noted. As shown in Table 1 the pycnidia on the stems are larger than those on the leaves but smaller than those on the fruits. On prune agar and Leonian's malt extract agar the pycnidia may enlarge to 2,000 or more microns in width and to more than 2000 μ in height.

The conidiophores upon which the spores are borne arise from the stromatic layer of the fungus structure over the entire inner wall (Plate 5, fig. 4). They are hyaline, short, and nearly filiform.

Within the pycnidia may be produced two types of spores which Edgerton and Moreland(2) termed as *Phyllosticta* and *Phlyotaena* types. The pycnospores, or spores of the *Phyllosticta* type, are single-celled, elliptical, or broadly elliptical, colorless, with usually two, rarely three, oil droplets within (Plate 5, fig. 2). This is the usual and common type of spore that develops in nature and also on artificial media. On the diseased fruits and leaves freshly collected from the field, it varies from 5.0 to 8.0 μ in length and from 1.7 to 3.6 μ in width. Almost the same measurements were true of the same type of spore which developed on various agar media and substrata used in the

foregoing studies of the characteristics of the fungus in artificial culture.

The stylospores, which are hyaline, filiform, and generally curved (Plate 5, fig. 3), measure commonly from 13.3 to 18.3 μ in length and from 1.0 to 1.7 μ in width. On the average they are 15.6 μ long and 1.3 μ wide. Stylospores which measure up to 28.2 μ are extremely rare. Spores of this type were not observed in examinations of several diseased leaves and fruits. A number of cankered stems obtained from infected eggplants, however, showed the presence of an appreciable quantity of this type of spore. A considerable number of stylospores were obtained from the pycnidia which developed on the dead stems of eggplants that were killed by the disease and left for three months in the field. These spores do not always develop in artificial cultures. In an examination of a series of tube cultures of the fungus on steamed eggplant stems some tubes showed the stylospores in appreciable quantity while others showed few or none. They were scantily produced on cucumber agar, potato-glucose agar, and papaya agar. Typical stylospores were developed by the fungus on the diseased stems of inoculated plants.

IDENTITY

As the fungus under study seemed at first to produce only the *Phyllosticta* type of spore, the writer believed in the beginning of this invesigation, that it might be *Phyllosticta hortorum* Speg., the occurrence of which in the Philippines was previously reported. Owing perhaps to the great scarcity of stylospores in specimens first examined, these structures escaped the writer's observation. In later examinations of crushed mounts of pycnidia from steamed eggplant stems and diseased stems from inoculated eggplant, structures similar to stylospores were found. Doubt was, therefore, entertained whether to call the fungus *Phyllosticta hortorum* or by another name. Since more stylospores were observed in other later examinations, the writer dismissed the idea that the fungus was *Phyllosticta hortorum* and instead believed that it might be identical with *Phomopsis vexans* (Sacc. and Syd.) Harter, the characteristics of which are the production of pycnospores (*Phyllosticta* type) and the typical structures known as stylospores (*Phlyctaena* type).

For purposes of verification diseased eggplant parts and tube cultures which showed the pycnidia of the fungus under inves-

tigation were sent to Dr. L. L. Harter of the United States Department of Agriculture, Bureau of Plant Industry, and in his letter dated January 21, 1936, he states:

> Sometime ago I received some tubes of cultures of an eggplant fungus and also some specimens of plant parts. You requested my opinion as to the identity of this fungus, especially as you thought it was identical with *Phomopsis vexans*, an organism described by me some years ago. The spores of your fungus seem to be slightly narrower than the one ordinarily met with in this country, usually it would not be surprising to find some variations. In fact a considerable amount of variation is often produced by the different media on which the organism grows. On examining one of your cultures, I find a considerable number of typical stylospores. The finding of these typical structures leads me to believe that the organism is identical with *Phomopsis vexans*, in spite of the slight variation in the size of the pycnospores.

According to Harter(4) this fungus was first known in the United States under the name of *Phyllosticta hortorum* Speg. It was also referred to later as *Phoma solani* Hals. and *Ascochyta hortorum* (Speg.) Smith. In later investigations on the same fungus Harter concluded that the above names were identical and that the genus to which these names were assigned was neither *Phyllosticta, Phoma,* nor *Ascochyta* but *Phomopsis.* He proposed the name *Phomopsis vexans* to supplant the name *Phoma vexans* used by Saccardo and Sydow for *Phoma solani* Hals.

The pycnospore measurements given above for the Philippine *Phomopsis vexans* appear to approximate closely those recorded by Harter who gave them as 5–8 x 2–2.8 μ, but they are lower than those reported by Edgerton and Moreland(2) who gave them as 6–8 x 3.0–4.0 μ. On the average the pycnospores of the Philippine fungus obtained from nature and from cultures on various media are perhaps slightly narrower than those of the American strain reported by Harter since their mean diameters lie between 2.1 and 2.4 μ.

The stylospores of the American *Phomopsis vexans* measure from 13 to 28 μ in length according to Harter and from 18 to 32 μ in length and from 1 to 1.8 μ in width according to Edgerton and Moreland(2). The stylospores of the American strain are on the average perhaps longer than those recorded for the Philippine strain, which measure commonly from 13 to 18.3 μ in length and from 1 to 1.7 μ in width. Since variation in spore size is also shown by *Phomopsis vexans* which occurs on eggplant in different places in the United States, it would not be surprising to find smaller spores of the same fungus in

the Philippines where climatic conditions are in many ways different from those existing in many parts of the United States. The discrepancies between the American *Phomopsis vexans* and the fungus under study as discussed above do not constitute sufficient reasons for separating the two organisms.

PATHOGENICITY

The disease was readily reproduced on eggplant seedlings and on fruit-bearing eggplants in infection experiments conducted in the greenhouse and in the field, respectively. The re-isolation of the fungus was not always made in all infection experiments, since the fungus produced the characteristic pycnidia on all inoculated plants, and in cases where it was made the fungus was readily recovered from spores planted in agar media by the spore dilution method. The variety of eggplant used in these experiments is known as Native Long Purple.

Infection of eggplant seedlings.—Eggplant seeds were planted either in pots or in seed boxes containing soil which had been autoclaved for two hours at a 15-pound pressure. Inoculations were made when the seedlings were 20 to 25 days old. With the different methods of inoculation tried, varying results were obtained.

In the first method half of a seed box of 20-day old seedlings were inoculated by spraying with a spore suspension prepared by crushing the pycnidia which developed on the diseased fruits. Spore contamination of the check seedlings in the other half of the box was prevented by covering the plants with Manila paper during the inoculation. The seed box was then placed in the moist chamber for 48 hours after which it was transferred to the greenhouse. The symptoms of infection were noted 8 days after inoculation. The inoculated plants showed 100 per cent infection a week later. After 35 days 90 per cent died of the disease (Plate 6, fig. 1), the typical symptom of which was blighting of affected leaves. None of the check seedlings showed the disease.

In the second method three pots, each containing 63 seedlings, were used; two were inoculated with the water suspension of spores obtained from a 22-day old steamed eggplant-stem culture of the fungus isolated from the leaf and the third was used as check. The three pots were all placed in the moist chamber. After 24 hours one of the inoculated pots was removed from the moist chamber and placed in the greenhouse, and after 72 hours the same was done with the other inoculated

pot and check pot. Signs of infection were shown after 6 days on inoculated plants kept for 72 hours, and after 10 days on those kept for 24 hours in the moist chamber. This result shows that a more rapid infection can be induced by longer exposure of both suscept and pathogen to humid conditions. Higher mortality of seedlings was observed in the pot kept for 72 hours than in the pot kept for only 24 hours in the moist chamber, the percentage of mortality recorded being 55.5 per cent for the former and 22.2 per cent for the latter. Blighting was also the typical symptom of the disease noted on the inoculated seedlings (Plate 6, fig. 2). Starting usually from the leaves, the disease progressed downward to the stems, causing the plants to fall over and die. The check seedlings were free from the disease.

In the third method four pots, each containing from 60 to 63 seedlings, were used; two were inoculated with a 22-day old eggplant-decoction-agar culture of the fungus isolated from the fruit, and the other two were left uninoculated as checks. One inoculated pot and one check pot were kept in the moist chamber for 48 hours after which they were transferred to the greenhouse. The second inoculated pot and the second check pot were not kept anymore in the moist chamber but were directly placed in the greenhouse. The inoculated pot which was kept in the moist chamber showed the disease after 8 days while the one that was placed directly in the green-house showed it after 12 days. A significant difference in the degree of infection and in the number of seedlings that died of the disease was noted between the two inoculated pots. Twenty-five days after inoculation the infection was 100 per cent in the pot kept in the moist chamber and 39 per cent in the one placed directly in the greenhouse while the seedlings that died of the disease were 39 per cent in the former and only 2 per cent in the latter. The disease was not shown on the check plants in either case.

In the fourth method two seed boxes, each containing autoclaved soil, were used; one was inoculated by mixing with the surface layer of the soil all of the diseased parts of eggplant seedlings which showed the pycnidia of the fungus, and the other remained uninoculated as check. Eggplant seeds were then planted in each box. The seedlings that emerged were about 90 per cent in the check box and about 60 per cent in the inoculated box. Three weeks later about 50 per cent of the seedlings that emerged in the inoculated seed box showed either damping-

off or blight symptoms of the disease, while the seedlings in the check seed box showed no disease.

In all the above inoculations it was observed that the fungus, whether isolated from the leaf or from the fruit, was capable of producing the disease on eggplant seedlings. However, greater virulence was shown by the fungus when the humidity was high and especially if exposure to humidity was prolonged. Inoculation by spraying with a spore suspension produced readily the disease on seedlings. The first recognizable symptoms of the disease on the leaves were the circular or irregular spots which later developed into typical blight disease. Progressing downward to the stems the disease thus caused the death of the seedlings. Damping-off symptoms were observed only on seedlings which were grown in infected soil. The pycnidia of the causal fungus always developed on the affected parts of the stems (Plate 6, fig. 3) and leaves of diseased plants.

Infection of eggplants under field conditions.—Two plots, each containing 32 eggplants planted at a distance of 70 centimeters in rows 70 centimeters apart, were separated by a space of more than two meters. One plot was inoculated with a spore suspension prepared from a 20-day old oatmeal-agar culture of the fungus isolated from the leaf and the other plot remained uninoculated as check. Inoculation was not done until weather conditions became favorable for infection. November 27, 1935, following a heavy rain [4] which lasted for more than one hour, inoculation was done. The humid and showery days which followed favored the fungus, and December 7, 1935, 10 days after inoculation, evident symptoms of the disease were recognized. Five days later all of the inoculated plants showed the characteristic cinnamon-buff (R) spots. The diseased leaves per plant 16 days after inoculation numbered from 2 to 12. On the average they represented 29.7 per cent of all the leaves on a plant, excluding those which were less than two centimeters in width. The spots counted on each plant varied from 4 to 125, with an average of 34.8. Seriously affected leaves turned yellow and fell off. No evidence of stem infection was noted three weeks after inoculation.

The disease, enhanced by favorable weather conditions, gradually became serious. The spattering of the rain which

[4] According to the records of the Central Station of the Weather Bureau the amount of rain on Nov. 27 was 17.0 mm. The Station is only about one kilometer from the experimental plots where the infection experiments were conducted.

occurred occasionally during December and January favored the discharge of the spores from the pycnidia which developed on the old spots on the leaves, thus the fruits and later the stems became seriously infected by the disease. A marked contrast between inoculated and check plots is shown in plate 7, figs. 1 and 2. Of the total number of fruits produced by the inoculated plot during the period from December 28, 1935 to March 31, 1936, 49.1 per cent showed rot symptoms due to the disease. As dry weather approached the disease on the leaves gradually disappeared. New cases of infection on the leaves were not much in evidence late in the season. However, the disease persisted on the stems and continued to cause the weakening of the plants, frequently resulting in their death. Of the 32 plants inoculated with the fungus, 29 died of the disease during the period from January 15, 1936, when the first dying plant was recorded, to April 18, 1936, when the writer's last observation was made. These dead plants represent about 90 per cent of the total number of inoculated plants.

The marketable fruits produced by the inoculated plot amounted to only one-tenth those produced by the check plot. None of the plants in the check plot showed the disease. The rotting off of one of the fruits which was obtained from one of the plants in this plot was found to be due to a species of *Phytophthora.*

DISSEMINATION

An infection on any part of the eggplant is caused by the mycelium of the fungus which penetrates the tissues. In new infections this mycelium originates usually from the spores that develop in the pycnidia. The spores which lodge in a favorable location on the host may germinate and penetrate the tissues if the existing weather conditions are favorable. Broken epidermis is not necessary for the fungus mycelium to establish itself within the host tissues since it is capable of penetrating unbroken epidermis. In planting infected seeds superficially coated with the mycelium, or contaminated with spores, germination of the seeds may take place, and the mycelium may, therefore, be carried over to the young plants as they emerge from the soil. The other young plants which do not show any infection in the same manner may sooner or later become infected if contaminated with the fungus from the neighboring diseased plants. An early infection on the foliar parts of eggplants in the field is frequently the direct result of transplant-

ing infected seedlings. When the disease is already in the field it spreads rapidly under favorable weather conditions. The presence of adequate moisture on the diseased parts of the plant may cause the extrusion of threadlike masses of pycnospores from the pycnidia. The spores in masses are embedded in a mucilagenous material and form into an irregular, threadlike coil as they ooze out of the ostiole of the pycnidium. The spores that have come out of the pycnidium are already available for dissemination.

New infection can only result if the spores are carried from one part of the plant to other parts, or from plant to plant. The splashing of the rain spreads the spores to nearby plants. Strong wind may perhaps aid also in the dissemination of the spores. It is also possible for the spores to adhere to the feet of insects and to be carried to places farther from the focus of infection. The spread of the disease may be occasioned also by the processes of weeding and cultivating. In the shipment of contaminated fruits or infected seeds for seed purposes the disease may be carried to new fields or into a new region.

SEASONAL DEVELOPMENT

A preliminary observation on the seasonal prevalence of Phomopsis disease shows that it may attack eggplant at any time of the year, but the extent of damage to the plant may vary according to existing weather factors. Since moisture is necessary for infection, the seriousness or reduced prevalence of the disease may be associated mainly with rainfall. During June, July, August, September, and October, when the precipitation is usually heavy, the disease may develop to epidemic proportions. In Arayat, Pampanga, and in Nueva Ecija, the disease was very serious on eggplant in August, September, and October, 1935 and 1936, when the rains were heavy. Leaf spots and fruit-rots were the prominent symptoms observed during the early part of the fruiting stage of the plants. They were followed by weakening of the plants due to infection on the stems, and death of seriously affected plants later. Occasional rains and showers in November, December, and January favored new infections, hence the disease was observed during these months on both seedlings and mature plants in an experimental plot which belongs to the Plant Breeding Section of the Bureau of Plant Industry at Manila. During the dry months (February, March, and April) new infections are seldom observed. The death of plants during the dry months was not usually due to

new infections but to the persistence of the disease on the stems of plants infected during the rainy period.

According to Chupp(1) the optimum temperature for the growth of *Phomopsis vexans* is 29.4° C., and it can still thrive at slightly higher and considerably lower temperatures. In Manila, for example, the air temperature may drop to as low as 14.5° C. and may rise to as high as 38.7° C. while the monthly mean may oscillate between 24.7° C. and 27.8° C. The temperature which supports the growth of *Phomopsis vexans* in the United States lies within the temperature limits existing in Manila. Hence, the favorable development of the disease at any time of the year in the latter place, in Nueva Ecija, in Arayat, Pampanga, and perhaps elsewhere in the Philippines where the climate is not very different from that of Manila. The failure of the disease to cause new infections during the rainless months is due to lack of adequate moisture on the surface of the susceptible parts of host for the germination of spores which lodge on them.

CONTROL MEASURES

SEED SELECTION

Since one of the common ways by which eggplants in the seedbed and subsequently those in the field are contaminated is by planting infected seeds, stress should, therefore, be put on the importance of seed selection. The grower should know the source of his seeds to be sure that he does not get them from an infected field. Only the seeds guaranteed by seed dealers as disease-free should be purchased. If there is no assurance that disease-free seeds are available, it is necessary for the grower to raise his own seeds. The seeds should be obtained only from ripe fruits picked from healthy, vigorous plants. According to Chupp(1) contamination of the seeds with the disease can be avoided by removing the peduncles and calyx of the fruit which may harbor the spores and then soaking the fruit in 1:1000 corrosive sublimate for ten minutes. The fruits are washed with water and the seeds extracted. After the seeds have been dried in the sun for about a week they should be kept in tightly stoppered bottles in a dry room.

SEED DISINFECTION

Seeds of unknown source should be disinfected before they are planted. According to Chupp(1) this procedure will kill the spores on the seeds but will not affect the mycelium in the seed. This author recommends soaking the seeds in 1:1000 corrosive

sublimate solution for ten minutes. In the absence of corrosive sublimate, formalin may be used. Soaking the seeds for 15 minutes in one part of commercial formalin to 300 parts of water was found by Edgerton and Moreland(2) to be satisfactory in reducing the amount of disease on seedlings grown from contaminated seeds.

HOT WATER TREATMENT

This treatment was found by Martin(5) to be satisfactory in killing the fungus in the seeds. He recommends soaking the seeds in hot water for either 30 minutes at 50° C. or 10 minutes at 55° C.

ERADICATION

As soon as the harvest is over, all of the plants in an infected field should be pulled and burned in order to kill the pathogen. This procedure will eliminate the source of infection for the other fields of eggplants that will be established in the neighborhood. The same procedure should be followed where crop rotation is practiced.

CROP ROTATION

Since *Phomopsis vexans* attacks only the eggplant, it probably can be starved out in an infected field by the process of crop rotation. It is not known how long this fungus can live in the soil and on plant refuse left in the field, but according to Edgerton and Moreland(2) it survives readily from one year to the next on fragments of old plants left in the field. These authors, therefore, recommend that the length of rotation with other crops for starving the parasite should not be less than three years.

VARIETAL RESISTANCE

Evidence of the existence of eggplant varieties resistant to Phomopsis disease was reported by Edgerton and Moreland(2). Of the many varieties of eggplant now grown in many different parts of the Philippines perhaps some may be resistant. An investigation on the possibility of controlling the disease by the use of resistant varieties is now being undertaken.

SPRAYING AND DUSTING

Dusting with copper lime dust or spraying with Bordeaux mixture has been generally recommended for reducing the disease and increasing the yield of an infected field. An experiment on the control of Phomopsis disease by spraying with Bordeaux mixture is discussed below.

BORDEAUX SPRAYING FOR THE CONTROL OF PHOMOPSIS DISEASE ON EGGPLANT

Materials and methods.—Two plots, one containing 160 plants and the other 32 plants, were used in this experiment. The plants were planted at a distance of 70 centimeters in rows 70 centimeters apart. The larger plot was divided into lots of 32 plants each and then the lots were numbered consecutively from I to V. The small plot was labelled Lot VI. Diseased plants for spraying test were made available by inoculating the plant with the pathogen. Inoculations were performed November 27, 1935, by spraying the plants with a spore suspension prepared from a 22-day old oatmeal-agar culture of *Phomopsis vexans*. Coincidentally, the weather conditions for a period of a few days following inoculation, being showery, favored infection, and the disease appeared on all plants 10 days after inoculation. The data on infection (fig. 1, charts 1 and 3) were recorded 15 days after inoculation.

The fungicide used in this spraying test was 1 per cent (4–4–50) Bordeaux mixture. The first spraying with this fungicide was done 16 days after inoculation, except in one of the lots (Lot IV) where it was given two days before inoculation. With a compressed-air sprayer the stems, fruits, and the upper and nether surfaces of the leaves of eggplants were given a good coating of Bordeaux mixture. The experiment as performed may be summarized as follows:

INOCULATED LOTS

Lot I—7 sprayings, weekly interval.
Lot II—5 sprayings, 2-week interval.
Lot III—4 sprayings, 3-week interval.
Lot IV—5 sprayings, 2-week interval. (Note.—This lot was inoculated 2 days after the first spraying of (4–4–50) Bordeaux mixture.)
Lot V—Unsprayed.

UNINOCULATED LOT

Lot VI—Unsprayed.

Discussion of results.—The data on infection which were recorded 15 days after inoculation, are shown in fig. 1, charts 1 and 3. The degree of infection in each lot is represented by the average percentage of leaves with spots and by the average number of spots per plant. Lots I, II, III, and V showed slight differences in the average percentage of leaves with spots (fig. 1, chart 1). In fact the infection in these lots can be considered as practically uniform since they showed almost the same average number of spots per plant (fig. 1, chart 3). Owing to the protection given by the Bordeaux mixture, Lot IV, which was ino-

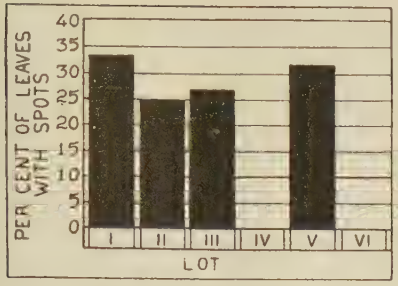


CHART 1

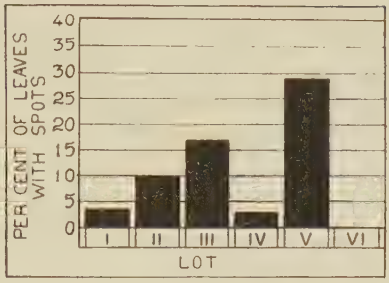


CHART 2

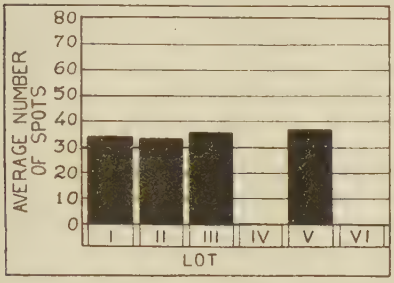


CHART 3

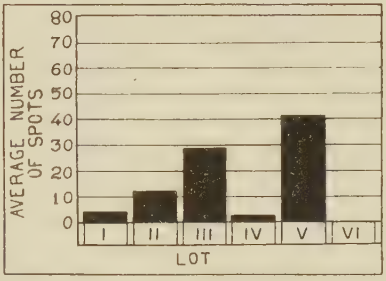


CHART 4

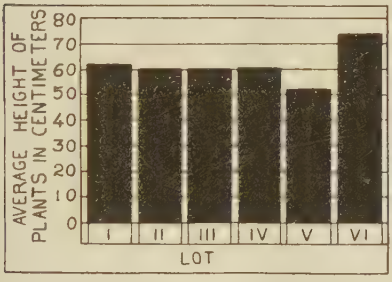


CHART 5

LEGEND:
(For Charts 2, 4 and 5)

LOT I SPRAYED WEEKLY
" II SPRAYED EVERY 2 WEEKS
" III SPRAYED EVERY 3 WEEKS
" IV SPRAYED EVERY 2 WEEKS
NOTE: THIS LOT WAS INOCULATED AFTER THE FIRST SPRAYING WITH BORDEAUX MIXTURE.
" V INOCULATED-UNSPRAYED
" VI UNINOCULATED-UNSPRAYED

FIG. 1. Charts showing the amount of infection of Phomopsis disease in the different lots of eggplants 15 days after inoculation with a water suspension of spores of the causal fungus and also the effect of Bordeaux spraying upon the plants and the disease.

CHART 1, average percentage of leaves with spots per plant in each lot, 15 days after inoculation with *Phomopsis vexans*. Lot IV which was inoculated after the first spraying with Bordeaux mixture and Lot VI which was uninoculated showed no infection by the disease.

CHART 2, average percentage of leaves with spots per plant in sprayed and unsprayed lots.

CHART 3, average number of spots per plant in each lot, 15 days after inoculation with *Phomopsis vexans*. Lot IV which was inoculated after the first spraying with Bordeaux mixture and Lot VI which was uninoculated showed no leaf spot due to Phomopsis disease.

CHART 4, average number of spots per plant in sprayed and unsprayed lots.

CHART 5, average height of plants in sprayed and unsprayed lots.

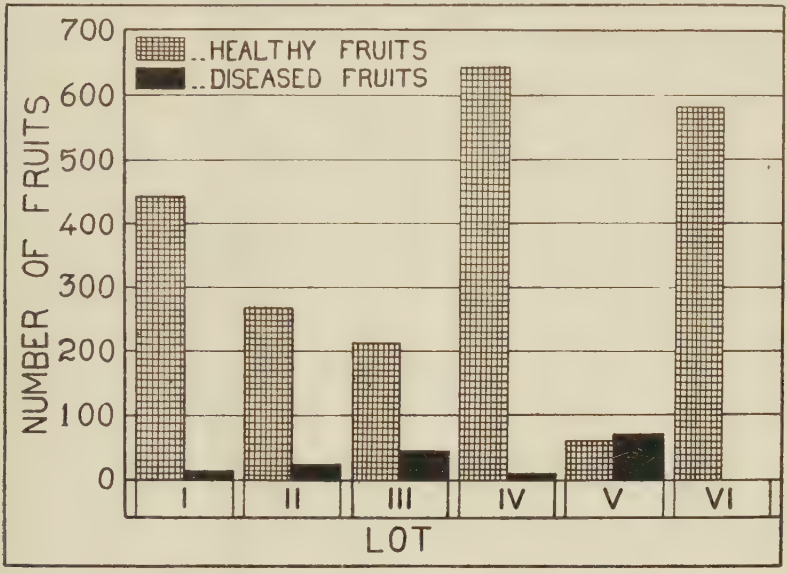
culated after it was given the first spraying of Bordeaux mixture and which received 2 sprayings of the same fungicide before the plants were examined for degree of infection, showed no symptoms of the disease. Lot VI, being uninoculated, did not show the disease.

An evident effect of Bordeaux spray upon the appearance of the plants was shown two months after inoculation or one and one-half months after the first spraying with Bordeaux mixture in the case of Lot IV. By comparing chart 1 and chart 2 and also chart 3 and chart 4 in fig. 1, it can be seen that Bordeaux spray had reduced the amount of infestation in Lots I, II, and III. Owing to the protection given by the Bordeaux spray, the disease in Lot IV progressed very slowly, hence the infection in this lot was light as shown in fig. 1, charts 2 and 4. Since the spray protected the newly formed leaves from the disease, theoretically the amount of infestation in Lots I, II, and III, as shown in fig. 1, charts 2 and 4, is the same as that shown in fig. 1, charts 1 and 3, respectively, minus the infected leaves which were shed and the corresponding spots thereon. Lot V, being inoculated but not sprayed, showed more leaf spot and a higher percentage of infected leaves than any of the remaining lots (fig. 1, charts 2 and 4). Owing to the rapid increase in number of the leaves of eggplants, and to the slackening of the disease on the leaves due to the approach of dry weather, in Lot V, an inoculated and unsprayed lot, the amount of infection two months after inoculation (fig. 1, charts 2 and 4) was almost the same as that two weeks after inoculation (fig. 1, charts 1 and 2).

The stand of the plants was very much affected by the presence of the disease (fig. 1, chart 5). The plants in Lot VI, being free from the disease, were in general higher than those in the inoculated diseased lots. In Lots I, II, III, and IV, where the amount of disease was minimized by the Bordeaux spray, the plants, the stand of which was more or less uniform, were generally higher than those in the inoculated and unsprayed lot (Lot V), clearly indicating that the disease causes stunting, and where it is most severe the plants are most stunted.

The yields are shown in fig. 2. The Bordeaux-sprayed lots, in all cases, gave higher yields than the inoculated and unsprayed lot. Of the sprayed lots, Lot IV gave the highest yield and at the same time showed the least fruit rot. This result was attributed to a certain amount of protection from infection by the disease given by the Bordeaux spray. Weekly sprayings of Bordeaux mixture gave better control than sprayings at longer

intervals. It seemed strange that Lot VI, which was uninoculated and unsprayed, gave lower yield than Lot IV. The only possible explanation is that since many fruits were allowed to ripen in Lot VI the plants in this lot might have been weakened to such an extent as to become less productive toward the close of the experiment.



LEGEND:

LOT I SPRAYED WEEKLY
II SPRAYED EVERY 2 WEEKS
III SPRAYED EVERY 3 WEEKS
IV SPRAYED EVERY 2 WEEKS
NOTE: THIS LOT WAS INOCULATED AFTER THE FIRST SPRAYING WITH BORDEAUX MIXTURE
V INOCULATED - UNSPRAYED
VI UNINOCULATED - UNSPRAYED

FIG. 2. Chart showing the yield in fruits of sprayed and unsprayed lots.

The spraying experiment was favored by good weather. The rains which occurred occasionally in December and January did not interfere with the spraying program. As the dry season approached less leaf spot was observed, and by the time the sprayings were stopped, foliar symptoms of the disease were hardly discernible. Fruit-rot was also minimized. However, the disease on the stems of sprayed and unsprayed plants per-

sisted and continued to cause the death of affected plants. At the close of the experiment about 90 per cent of the plants in the inoculated and unsprayed lot and about 20 per cent in the sprayed lots died, due to the attack of the disease on the stems (Plate 8). No Phomopsis disease developed in the uninoculated lot (Lot VI).

The foregoing results of the spraying experiment which was conducted from November, 1935 to April, 1936, show that Phomopsis disease of eggplant can be controlled successfully by six weekly sprayings with 4–4–50 Bordeaux mixture (Plate 7, fig. 3). Five bi-weekly sprayings with the same fungicide before the disease is well established in a field appear to be highly beneficial and prevent to a great extent successful infection of the plants by the disease. The increase in yields of the sprayed lots over the inoculated and unsprayed lot was more than seven fold in the first case and more than ten fold in the second case, the costs of spraying per plant in the two cases being ₱0.015 and ₱0.012, respectively. From the above preliminary investigation it appears that Bordeaux spraying for the control of Phomopsis disease can be undertaken with a certain margin of profit unless adverse weather factors, insect infestations, and an outbreak of other diseases which cannot be controlled by Bordeaux spray, upset the yield. There is, however, no assurance that the above control will prove beneficial in climates with abundant rainfall.

SUMMARY

A severe outbreak of Phomopsis disease which attacks the aërial parts of eggplants, producing leaf spot, stem canker, and fruit-rot, occurred in Tanag, Arayat, Pampanga Province, in September and October, 1935. All of the plants in the field, about 7,000 in number, showed the disease with leaf spot as the more prominent symptom. About 50 per cent of the eggplants were severely defoliated due to serious leaf-spot infection. Stem canker caused the death of a number of plants. In two examinations made at an interval of three weeks, the fruits in the field that were destroyed by the disease were 37 per cent and 64 per cent, respectively. It also destroyed in transit 10 per cent of the first harvest and 20 per cent of the second. In September and October, 1936, the same disease was also found attacking seriously the eggplants in Nueva Ecija.

The symptoms of the disease on the different parts of the eggplant (stems, leaves, fruits, and seedlings) are described and illustrated.

The disease is caused by *Phomopsis vexans* (Syd. and Sacc.) Harter, a fungus the typical characteristic of which is the production of subglobose or irregularly-shaped pycnidia in which two types of spores, the elliptical single-celled, hyaline spores known as pycnospores and the filiform hyaline, curved spores known as stylospores, may be produced. The Philippine *Phomopsis vexans* produces most commonly the elliptical spores under natural conditions and by artificial culture. The stylospores which are usually rare may be produced in considerable number from the pycnidia that develop on the dead stems of eggplants killed by the disease and left in the field.

The results of inoculation experiments show that the disease can readily be reproduced on seedlings in the greenhouse and on mature plants in the field by spraying with a water suspension of spores obtained either from artificial culture or from the diseased parts of the plant.

Since humid weather conditions are necessary for the rapid infection of the eggplant by the fungus, the disease was observed to be more destructive during the rainy months than during the dry months.

A preliminary spraying experiment conducted during the normal growing season of the eggplant showed that Phomopsis disease can be greatly reduced and the yield of fruits increased seven fold by six weekly sprayings of diseased plants with 4–4–50 Bordeaux mixture. In a healthy field where there is danger of infection bi-weekly sprayings with 4–4–50 Bordeaux mixture aid greatly in preventing successful infection of the plants by the disease.

The other control measures that may be suggested are: planting of healthy seeds; soaking of suspicious or infected seeds in either 1:1,000 corrosive sublimate solution for 10 minutes or in formalin solution (one part of commercial formalin to 300 parts of water); soaking the seeds in hot water for either 30 minutes at 50° C. or 10 minutes at 55° C.; burning the plants in an infected field after the harvest to kill the pathogenes and eliminate the source of infection to other fields; and 3-year crop rotation.

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ILLUSTRATIONS

Plate 1

Fig. 1. An eggplant attacked by Phomopsis disease showing four infected fruits; about $\times 1/10$. (Photograph by S. Gomez of the Division of Publications.)

2. An eggplant leaf showing the typical leaf spot symptoms of Phomopsis disease; about $\times 3/5$. (Photograph by C. S. Angbengco of the Bureau of Science.)

3. A portion of an eggplant leaf showing the pycnidia of *Phomopsis vexans* on old spot lesions; about $\times 1.3$. (Photograph by C. S. Angbengco of the Bureau of Science.)

Plate 2

Fig. 1. Portions of eggplant stems showing the formation of adventitious roots on the stems above the points of infection caused by Promopsis disease; about $\times 5/6$.

2. Portions of eggplant stems showing the Phomopsis disease at the nodes. Infection at the nodes causes dropping off of the leaves or death of the leaf buds or branches which arise from them; about $\times 5/6$.

3. A portion of the main stem of an eggplant showing an enlarged blotch caused by Phomopsis disease; about $\times 5/6$.

4. Portions of eggplant stems showing the pycnidia of *Phomopsis vexans* on the old lesions; about $\times 5/6$. (Photographs by C. S. Angbengco of the Bureau of Science.)

Plate 3

Fig. 1. Phomopsis disease on eggplant fruits. Note that the coalescence of several lesions has formed large rotted areas on the fruits; about $\times 7/15$.

2. A portion of an eggplant fruit attacked by Phomopsis disease showing the pycnidia of the causal fungus on the rotted areas; about $\times 1 1/3$.

3. Mummied eggplant fruits blackened by numerous pycnidia of *Phomopsis vexans;* about $\times 2/3$. (Photographs by C. S. Angbengco of the Bureau of Science.)

Plate 4

Fig. 1. Seven-day-old plate cultures of *Phomopsis vexans* on various agar media. The colonies are lobed at edges; about $\times 1/4$.

a, Eggplant agar.
b, String-bean agar.
c, Potato-glucose agar.
d, Prune agar.
e, Cornmeal agar.
f, Leonian's malt agar.
g, Oatmeal agar.
h, Papaya agar.

FIG. 2. Plate cultures of *Phomopsis vexans* on two agar media showing the development of black pustules described in the text as pycnidia; about ×⅝.
a, Oatmeal agar.
b, Eggplant agar.

3. Test tube cultures of *Phomopsis vexans* on three agar media showing its pycnidia; about ×⅝.
a, Prune agar.
b, Eggplant agar.
c, Oatmeal agar.
(Photographs by C. S. Angbengco of the Bureau of Science.)

PLATE 5

FIG. 1. A section through a group of pycnidia that developed on the rotted area of an eggplant fruit. Note the subglobose shape of the pycnidia; about ×75. (Photomicrograph by C. S. Angbengco of the Bureau of Science.)

2. Pycnospores of *Phomopsis vexans;* about ×800.
3. Stylospores of *Phomopsis vexans;* about ×800.
4. A section through a pycnidium on the leaf showing the arrangement of the conidiophores along the inner wall of the pycnidium; about ×450.

PLATE 6

FIG. 1. A box of eggplant seedlings showing the Phomopsis disease on half (left) inoculated with a water suspension of spores of *Phomopsis vexans* obtained from the diseased fruits and healthy seedlings on the uninoculated half (right); about ×⅙. (Photograph by S. Gomez of the Division of Publications.)

2. Potted eggplant seedlings. Left pot, healthy seedlings; note the blight symptoms of Phomopsis disease on the leaves of inoculated seedlings; about × ⅙. (Photograph by S. Gomez of the Division of Publications.)
3. Portions of the stems of eggplant seedlings inoculated with *Phomopsis vexans* showing the pycnidia on the attacked parts; about × 2. (Photograph by C. S. Angbengco of the Bureau of Science.)

PLATE 7

FIG. 1. A portion of a plot of eggplants inoculated with *Phomopsis vexans.* Note the stunted appearance of the plants due to the attack of the disease; about ×1/18.

2. A plot of uninoculated eggplants showing the absence of Phomopsis disease; about ×1/18.
3. Inoculated, unsprayed lot (left) and inoculated, sprayed lot (right) of eggplants. Note the difference in the stand of the plants; about × 1/17. (Photograph by S. Gomez of the Division of Publications.)

Plate 8

A group of eggplants attacked seriously by Phomopsis disease on the stems. The plants are wilted and the branches have fallen over due to infection on the lower parts of the stems; about $\times \frac{1}{20}$. (Photograph by G. Panlilio of the Bureau of Science.)

Text Figures

Fig. 1. Charts showing the amount of infection of Phomopsis disease in the different lots of eggplants 15 days after inoculation with a water suspension of spores of the causal fungus and also the effect of Bordeaux spraying upon the plants and the disease.

Chart 1, average percentage of leaves with spots per plant in each lot, 15 days after inoculation with *Phomopsis vexans*. Lot IV which was inoculated after the first spraying with Bordeaux mixture and lot VI which was uninoculated showed no infection by the disease.

Chart 2, average percentage of leaves with spots per plant in sprayed and unsprayed lots.

Chart 3, average number of spots per plant in each lot, 15 days after inoculation with *Phomopsis vexans*. Lot IV which was inoculated after the first spraying with Bordeaux mixture and Lot VI which was uninoculated showed no leaf spot due to Phomopsis disease.

Chart 4, average number of spots per plant in sprayed and unsprayed lots.

Chart 5, average height of plants in sprayed and unsprayed lots.

Fig. 2. Chart showing the yield in fruits of sprayed and unsprayed lots.

PLATE 1.

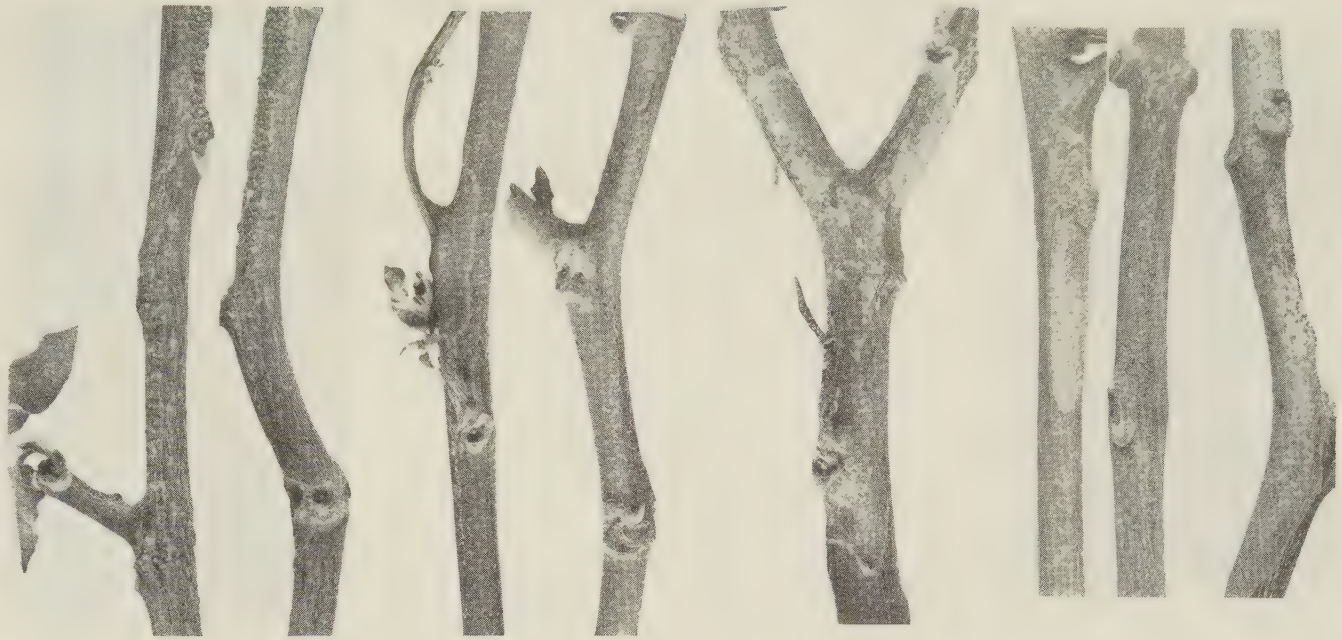


PLATE 2.

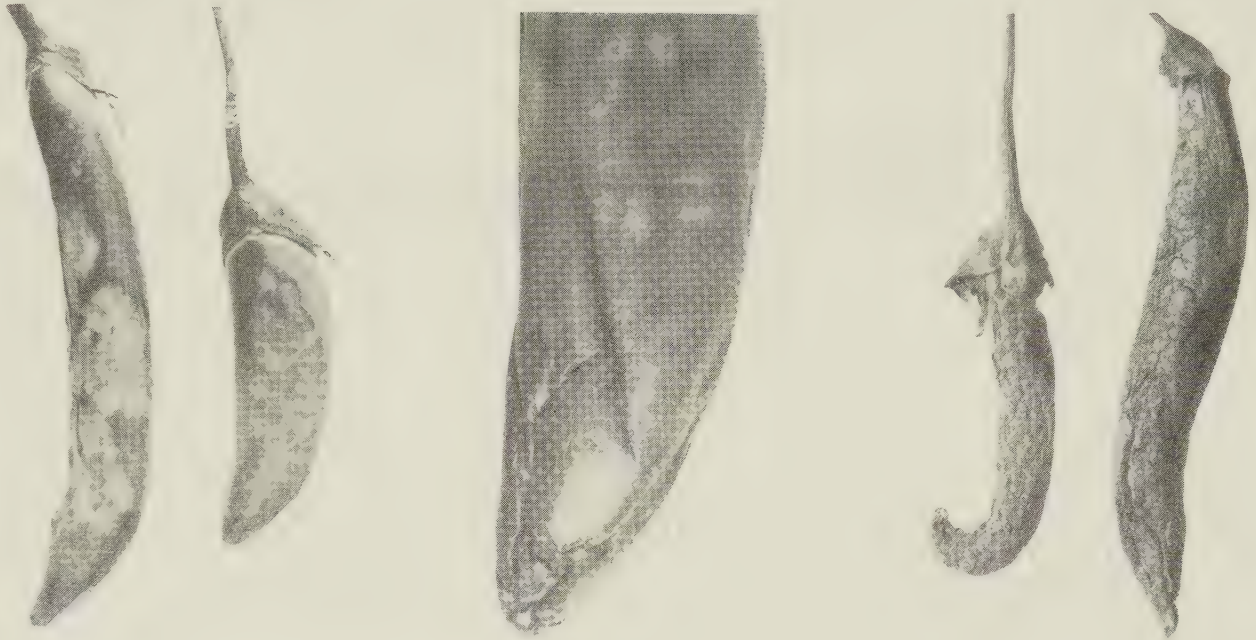
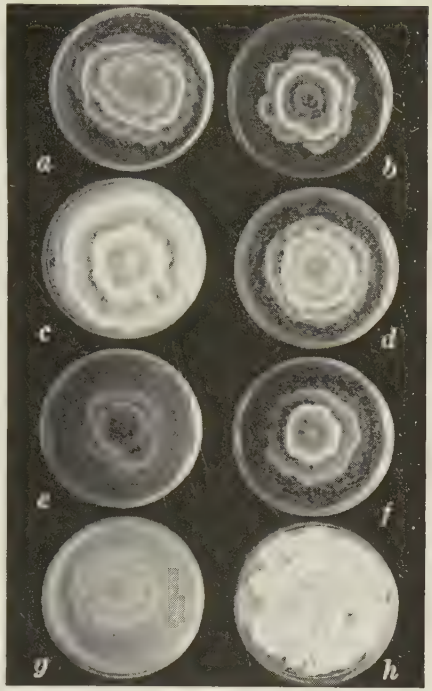
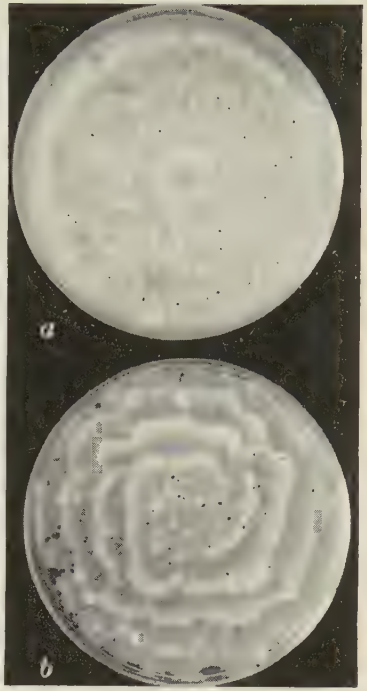
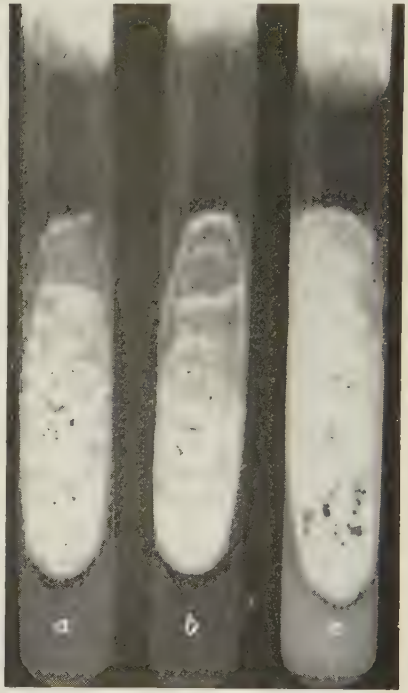


PLATE 3.







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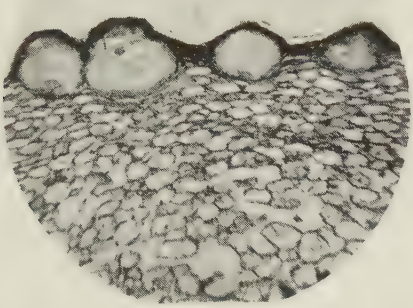

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PLATE 5.

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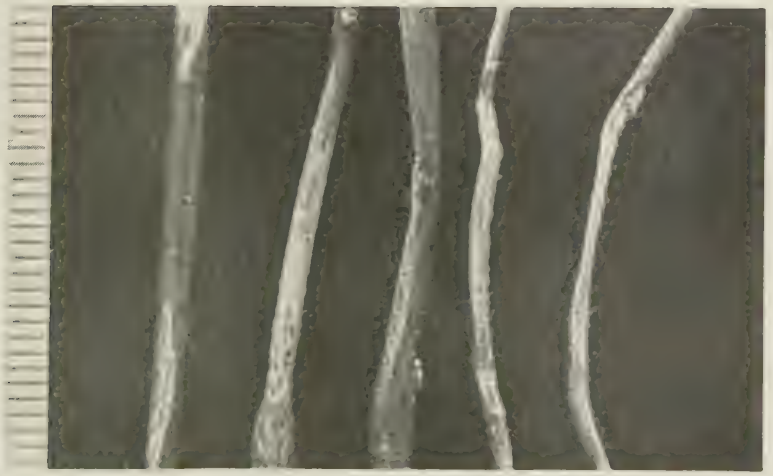

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PLATE 6.

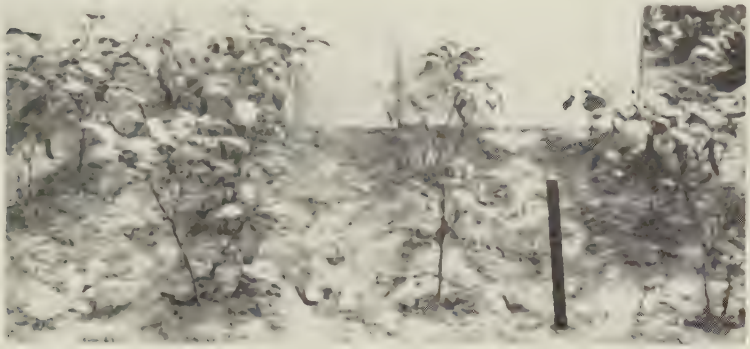

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PLATE 7

PLATE 3.

PRELIMINARY STUDIES ON THE USE OF THE BERMUDA ONION AS A ROTATION CROP WITH LOWLAND RICE

By PEDRO A. RODRIGO

Of the Horticulture Section, Bureau of Plant Industry

FOUR PLATES

Vast areas of lowland-rice fields generally remain idle after the rice crop has been harvested for lack of suitable crops to be grown on them. In Ilocos Norte native onions and garlic are planted after the lowland-rice crop. The method of culture is simple yet practical—fitting well the peculiar conditions obtaining in most lowland-rice fields, where the soil is heavy and sticky and therefore hard to prepare for ordinary culture. The practicability of this method and the search for crops that can be grown in rotation with lowland rice led the writer to undertake the present study. The aim of this work, therefore, was to find out whether Bermuda onion (big-bulbed type) can be grown in lowland-rice fields after the rice crop has been harvested.

The present work was undertaken at the defunct Alabang Rice Station, Muntinlupa, Rizal; at the Central Experiment Station, Malate, Manila; at the Sta. Maria Propagation Station, Sta. Maria, Ilocos Sur; and in Batac, Ilocos Norte. The study was started in January, 1933, and was completed in May, 1936.

MATERIALS AND METHODS

Bermuda onion seedlings were used. They were raised in the same way in which onion seedlings are grown for the ordinary method of culture. The rice fields used were of clay loam to clay in texture. They were believed to represent the average soil texture of Philippine rice fields. At the Central Experiment Station, the small cemented paddies constructed for rice breeding were used. But even here typical rice-paddy soils from Alabang were brought in to fill the paddies for rice breeding work.

The preparation of the paddies for planting consisted (1) in cutting the rice straw close to the ground and removing all weeds, and (2) in spreading rice straw over the cleaned paddy

to a thickness of from 10 to 15 centimeters. In cases where the soil was rather dry it was irrigated before the straw mulch was spread. Where fertilizer was used, the latter was spread over the soil and then sprinkled with water before the mulch was placed. Care was taken to have the right moisture content of the soil before spreading the mulch, otherwise the newly transplanted onion seedlings would have a very poor start in growth. Where the soil was too moist it was first exposed to the sun to dry so as to get the right moisture content before the mulch was spread. Moisture conditions are best when the soil begins to crack, but is still soft enough to allow the insertion of the tip of the forefinger.

Transplanting.—Transplanting was done soon after the mulch was spread. A string was used to guide the planting. Rows were then laid out 25 centimeters apart and the seedlings along these rows were set 10 centimeters apart. Before transplanting, the onion seedlings which were from 40 to 45 days old were lifted up from the seed bed and their roots pruned to a length of about 2 to 3 centimeters. For the planting of the seedlings narrow openings were made through the straw mulch with the hands, where holes about 1 to 1½ centimeters deep were made with a blunt dibble. The seedlings were inserted into these holes and the soil pressed down simultaneously at the bases of the seedlings. The openings on the straw mulch were left in such a way as to check rapid evaporation and at the same time to allow the leaves of the seedlings to come out.

Care of the crop.—The culture at the Central Experiment Station received no care practically except that they were irrigated once or twice, as the soil became dry. The irrigation was done before the formation of bulbs.

EXPERIMENTS AND RESULTS

The results presented in this paper were obtained from trial tests made in three seasons, although the studies were conducted over four seasons. The first year test which was conducted at the defunct Alabang Rice Station, Muntinlupa, Rizal, in the early part of 1933, was almost a total failure because of heavy rain that soaked the experimental plots soon after transplanting. The plants rotted or were totally stunted except a few on a rather elevated spot near the border of the paddy. These few plants grew to maturity and produced medium-sized bulbs of good texture, thus giving some encouragement for further trial tests.

The trial tests made at the Central Experiment Station, Malate, Manila, in 1933–34 and in 1934–35, furnish most of the data presented in this paper. The stand of the plants in both years was good, except that a goodly portion did not mature normally because of the severe attack of thrips. Table 1 presents the result of the 1933–34 test and Table 2 gives the data of the 1934–35 plantings.

TABLE 1.—*Yield of the 1933–34 planting of Bermuda onion in a rice paddy at the Central Experiment Station, Manila.*

Plot No.	Area of plot.	Not fertilized.	Fertilized with nitrophoska (16.5-16.5-20)		
			At 100 kilos per hectare.	At 200 kilos per hectare.	At 300 kilos per hectare.
	sq. m.	*Kg.*	*Kg.*	*Kg.*	*Kg.*
1	5	1.12	5.02	6.68	5.54
2	5	2.45	3.62	3.73	3.47
3	5	1.95	3.98	4.39	9.25
4	5	2.05	3.07	2.14	8.69
5	5	1.72	1.49	4.68	2.78
6	5			3.89	4.27
7	5			3.51	4.42
8	5			2.88	4.99
9	5			4.39	4.83
10	5			2.32	2.24
Mean		1.86±0.13	3.44±0.33	3.86±0.27	5.05±0.47
S. D.		0.43±0.09	1.07±0.23	1.24±0.19	2.18±0.33
C. V.		23.10±0.53	34.01±8.13	32.10±5.34	43.10±7.72
Computed yield per hectare		3,720	6,880	7,720	10,100

TABLE 2.—*Yield of the 1934–35 planting of Bermuda onion in a rice paddy at the Central Experiment Station, Manila.*

Plot No.	Area of plot.	Not fertilized.	Fertilized with Nitrophoska (16.5–16.5–20) at 300 Kg. per Ha.
	Sq. m.	*Kg.*	*Kg.*
1	5	3.44	9.64
2	5	3.84	8.02
3	5	4.65	7.69
4	5	4.26	9.30
Mean		4.05±0.15	8.66±0.28
S. D.		0.45±0.11	0.82±0.20
C. V.		10.60±2.53	9.46±2.28
Computed yield per hectare		8,100	17,320

In practically all the tests the seedlings recovered rapidly from the effect of transplanting. In the first test at the Central Experiment Station, there was a comparatively big number of plants that showed lack of vigor. Also, in places where the soil was rather too moist when the straw mulch was spread, the seedlings had a very slow recovery; they were yellowish and stunted. The crops produced, except those that were badly attacked by thrips, matured normally, from 86 to 121 days after transplanting.

Unlike the case in the ordinary method of onion culture the bulbs were formed on the surface of the soil just below the straw mulch. In the first test there was a comparatively large number of the bulbs produced that were abnormal. Upon examination it was found that the seedlings must have been planted rather deep and as a result the bulbs were engulfed or encased in the soil as it hardened.

The trial tests with coöperators at the Sta. Maria Propagation Station, Santa Maria, Ilocos Sur, during the 1935–36 season, were failures. Failure was due to (1) improper cleaning of the field before spreading the straw mulch, (2) very thin and improperly spread straw mulch, and (3) deep planting.

The results obtained in the trial test in Batac, Ilocos Norte, with a coöperator during the 1935–36 planting season in unirrigated rice fields, are presented in Table 3.

TABLE 3.—*Coöperative trial planting of Bermuda onion in an unirrigated rice paddy in Batac, Ilocos Norte, 1935–36*

Date transplanted	Jan. 8, 1936.
Date harvested	Apr. 15, 1936.
Number of days to maturity (from transplanting)	100
Area planted	357 sq. m.
Yield:	
Big bulbs (6–7 cm. in diameter)—38.8 kg.	
Medium bulbs (4–5 cm. in diameter)—42.8 kg.	96.8 kg.
Small (below 4 cm. in diameter)—15.2 kg.	
Computed yield per Ha.	2,711 kg.

While the stand of the crop was not very good, due, perhaps, to the rather late planting, the crop attracted wide attention among the farmers of the community, particularly where garlic and native onion are raised. The coöperator, Mr. Flavio Rodrigo, and a number of his neighbors assured the writer that in the next planting season they would plant more of the Bermuda onion according to the method discussed in this paper, even to the extent of sacrificing their garlic culture. The bulbs pro-

duced were only of medium size, the biggest having an average diameter of from 6 to 7 centimeters. However, they were comparatively hard, the neck small, and the scale was firm and full and comparatively thick.

DISCUSSION OF RESULTS

Recovery of seedlings.—As stated in the results, the seedlings recovered rapidly from the effect of transplanting. The comparatively large number of plants that were later noticed lacking in vigor, upon examination, was found not properly set in the soil when transplanted. There was a hollow or space below each plant (see Plate 1, fig. 1), hence, they could not anchor properly and gave poor growth. The cause was the boring of unnecessarily deep holes by the planter for the seedlings; these holes were not filled with soil particles after planting because of the peculiar condition of the soil. To escape this trouble, the holes into which the seedlings are to be set should be made with a blunt dibble and should not be more than 1 to 2 cm. deep. The seedlings should be set in the holes with their roots reaching the solid ground (see Plate 1, fig. 3). The soil around the base of the seedlings should also be pressed lightly so as to insure proper and rapid rooting.

Another cause of trouble in the first test at the Central Experiment Station was the planting in too wet soil. The seedlings had a very slow recovery and were yellowish in color and appeared stunted. To obtain rapid recovery and vigorous growth, the soil should have the right moisture content at the time of transplanting. The mulch should not be spread while the soil is still too moist.

Formation of the bulbs.—Normally, the bulbs were formed and developed on the surface of the soil, that is, between the straw mulch and the soil. The developing bulbs were kept firm in place by their roots but as they matured their roots became brittle, which made the picking of the bulbs easy. This was the case when the seedlings were planted 1 to $1\frac{1}{2}$ cm. deep. As the seedlings attained the stage of bulb formation, the bases of the plants grew out of the soil. On the other hand, when the seedlings were set deep in the soil (see Plate 1, fig. 2), the bulb-forming portion of the plants was not able to emerge, and, as a result, the bulb was formed inside the soil. As the soil became dry and hard, the bulb was encased or engulfed, and, as a result, became small and abnormal (see Plate 3, fig. 2). It is, therefore, essential for the seedlings to be set at the right depth (see

Plate 1, fig. 3) to produce normally formed bulbs (see Plate 3, fig. 1).

Yield.—As may be seen in Tables 1, 2, and 3, the results of this study are of far-reaching practical value. They point out a way of utilizing the extensive areas of lowland-rice land that generally lie idle for almost half a year for want of some suitable crops that can be grown in them. In the 1933–34 test the average yield of every 5 sq. m. plot was 1.86 ± 0.13 kilos for the unfertilized plots; 3.44 ± 0.33 kilos for those receiving 100 kilos of nitrophoska (16.5–16.5–20) per hectare; 3.86 ± 0.27 kilos for those treated at the rate of 200 kilos per hectare of the same fertilizer; and 5.05 ± 0.47 kilos for those fertilized at the rate of 300 kilos per hectare. In the 1934–35 test the average yield for the same size of plots (5 sq. m.) of the unfertilized paddy was 4.05 ± 0.15 kilos, while the fertilized paddy at the rate of 300 kilos per hectare gave an average yield of 8.66 ± 0.28 kilos. Reducing these yields to the hectare basis, the average production in the 1933–34 test was 3,720 kilos for the unfertilized plots; 6,880 kilos for those fertilized at 100 kilos per hectare; 7,720 kilos for the 200-kilo rate; and 10,100 kilos for the 300-kilo rate per hectare. In the 1934–35 test the average yield per hectare was 8,100 kilos for the unfertilized plots; and 17,320 kilos for the plots fertilized at the rate of 300 kilos per hectare. It may be remarked here that the average yield per hectare of the ordinary onion culture ranges from 10,000 to 15,000 kilos.

Effect of fertilizers on the yield.—While this study was undertaken mainly to find out whether the Bermuda onion can be grown after the lowland-rice crop, and the different rates of fertilizer application were only measures to insure a better stand of the crop, it can be seen in Tables 1 and 2 that the fertilizers applied exhibited decided beneficial effects. The effect on the yield was more pronounced with the heavier rates of application. The best rate of application for certain types of soil as well as the method and the cost of application, however, are yet to be worked out.

Yield in non-irrigated planting.—The results of the coöperative test in Batac, Ilocos Norte (see Table 3), appear to be poor, but after a consideration of the distance of planting (25 cm. by 15 cm.) employed, they seem to be just as significant as the results at the Central Experiment Station. The crop was planted on January 8, 1936, in a field that had no irrigation facilities, and in which during the growing period of the crop no rainfall had been recorded. As seen in Table 3, the yield was 96.8 kilos

for a plot having an area of 357 sq. m. or a computed yield of 2,711 kilos per hectare. The comparatively low yield was due mostly to the wide spacing and partly to the late planting (January 8, 1936). The fact that a big portion of the bulbs produced attained an average diameter of 6 to 7 centimeters shows the significance of the results. Also, the fact that the crop was raised without the use of any irrigation water makes the results doubly significant, because of the presence of extensive areas of rice land that have no irrigation. At least these are potential areas for Bermuda-onion production. Further studies to determine the utility of unirrigated lowland-rice fields for onion culture should be undertaken. The test may include the planting of early and drought-resistant varieties.

Quality of the crop.—One important feature of the results obtained in this study was the quality of the crop. The bulbs produced were only of medium size (about 50 per cent attaining an average diameter of 6 to 7 centimeters) but they were firm and solid and the neck was conspicuously small, unlike the Bermuda onion produced under the ordinary method of culture. The scale was also full and firm and not brittle, perhaps, because of regulated drying attributable to the conditions under which they were produced. The bulbs having been developed between the soil and the straw mulch, there was slow but tempered drying, which made the scale solid. Also, with the straw mulch, the drying of the soil must have been gradual, and, therefore, there was no abrupt arrest of growth, which very often occurs under ordinary methods of culture.

SUMMARY AND CONCLUSIONS

This paper presents the results of a four-year study on the use of the Bermuda onion as a rotation crop with lowland rice. The results have a great practical application as they point out a way of utilizing a portion of the extensive rice areas that remain idle for at least half of the year. The method for growing the Bermuda onion here presented does away with the expensive preparation of the land practiced in the ordinary onion culture. Also, it does away with cultivation and weeding, two big items of expense.

From the results presented, the following conclusions may be justified:

1. The Bermuda onion was grown rather successfully in rotation with lowland rice whether with or without irrigation. At the Central Experiment Station, Manila, the computed average

yield per hectare in unfertilized but irrigated field was from 3,720 kilos to 8,100 kilos, while in the fertilized—300 kilos per hectare of nitrophoska (16.5–16.5–20)—and irrigated field, the average computed yield was from 10,100 to 17,320 kilos per hectare. In Batac, Ilocos Norte, the computed yield per hectare from unirrigated and unfertilized field was 2,711 kilos.

2. The onion seedlings transplanted in too moist soil had a very slow recovery. Those planted where the surface of the soil was beginning to crack recovered rapidly from the effect of transplanting and they had vigorous growth.

3. The Bermuda onion planted in an unplowed but mulched rice paddy at the Central Experiment Station responded well to the use of nitrophoska, a complete fertilizer containing 16.5 N–16.5 P_2O_5 and 20 K_2O. In the first test the mean yield for every 5-square meter plot of the different rates of application was 1.86 ± 0.13 kilos for the check plot, 3.44 ± 0.33 kilos for the plot fertilized at the rate of 100 kilos per hectare, 3.86 ± 0.27 kilos for the 200-kilo application, and 5.05 ± 0.47 kilos for the 300-kilo application. In the second test the mean yield per 5–square meter plot was 4.05 ± 0.15 kilos for the check or unfertilized plot and 8.66 ± 0.28 kilos for the 300-kilo application.

4. The onion crop matured from 86 to 121 days after transplanting; this was earlier than those planted under the regular method of onion culture.

5. Normally, the bulbs were produced on the surface of the soil just below the mulch. Plants set more than 2 centimeters deep produced bulbs that were abnormal. The bulbs were not formed on the surface of the soil; they were encased in the hardened soil.

6. The bulbs produced in all the tests were mostly of the medium size, which is on demand in the markets. The quality was as a whole superior to the Bermuda onion produced under the ordinary method of culture. The bulbs were firm, the neck small, and the scale full and not so brittle.

ILLUSTRATIONS

Plate 1

Fig. 1. An onion seedling that was not properly planted. Note the deep hole made by the planter, and as he tried to set the seedling at the proper depth, a vacuum (*V*) was left below it and the seedling was "hanging" and thus it could not easily anchor itself properly.

2. An onion seedling planted too deeply. This is the main cause of small and abnormally formed bulbs.

3. An onion seedling properly planted. Note the roots touching the solid ground, and the seedling itself had been set at the right depth. SM = Straw mulch; S = Soil.

Plate 2

Fig. 1. Some onion bulbs produced under unplowed but mulched lowland rice-field conditions. Note the smaller size of the bulbs but with more tight scales.

2. Some onion bulbs produced under ordinary method of culture.

Plate 3

Fig. 1. Some onion bulbs produced in mulched lowland rice paddy—normally formed.

2. Some onion bulbs produced in mulched lowland rice paddy. Abnormally formed because of too deep planting.

Plate 4

Some rice paddies at the Central Experiment Station, Malate, Manila, planted to onions. The paddies after the rice crop was harvested were cleaned, and straw mulch was spread without plowing.

PLATE 1.

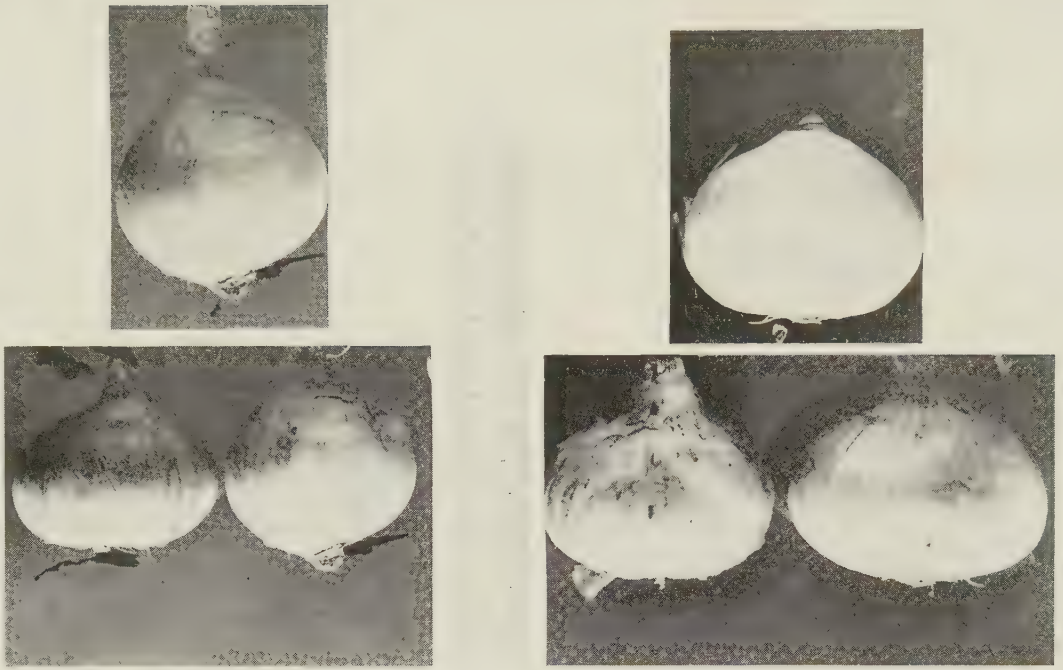
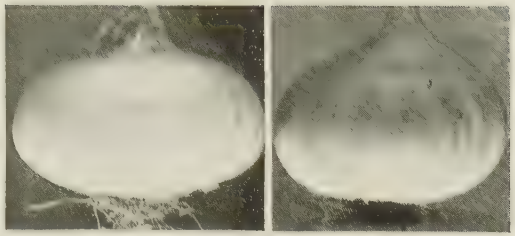


PLATE 2.



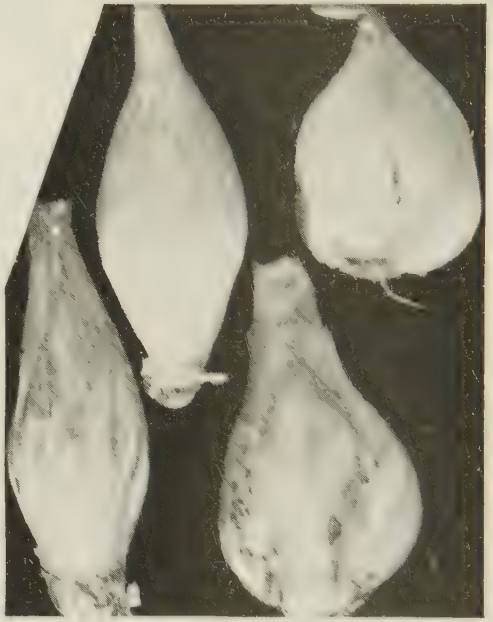


PLATE 3

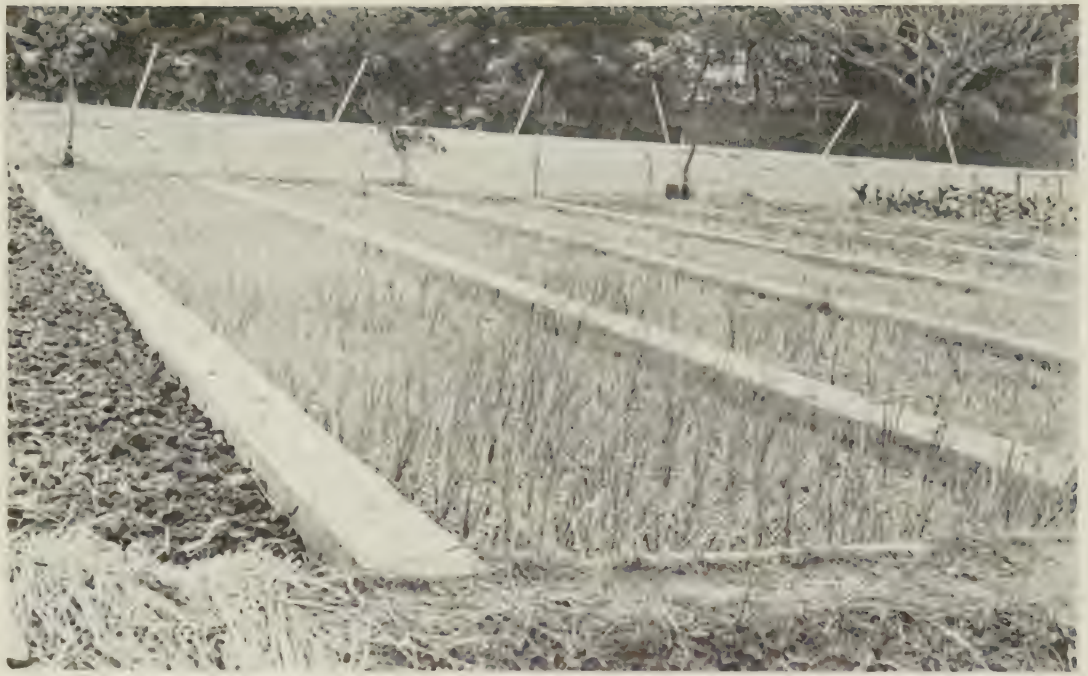


PLATE 4.

THE EFFECT OF TIME OF SHADING TOBACCO UPON YIELD AND QUALITY OF WRAPPER-LEAF TOBACCO IN THE PHILIPPINES

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FIVE PLATES

The formative effect of sunlight which causes changes both in form and structure of plant organs, specially those of the leaves, is the subject of experimentation on the production of fine-grade cigar-wrapper. To be a good wrapper, the leaf should be uniform in color, thin, and elastic, and should have fine veins. These qualities can be produced by modifying the habitat factors of the tobacco plant, among which is sunlight.

The purpose of shading tobacco plants with cheesecloth is to reduce the intensity of sunlight falling on the tobacco leaves. This method was first tried in Florida about 1896(2) and later in 1900(5). The officials of the Connecticut Agricultural Experiment Station and the judges who examined the tobacco, as well as the manufacturers who used the wrapper-leaf produced by shading, pronounced it equal if not superior to the tobacco imported from Sumatra. The successful growing of fine tobacco under shade is not confined to the United States, but is carried on also in Cuba and Porto Rico. Paguirigan(3) in 1916 also demonstrated in the Philippines, particularly at Los Baños, Laguna, the possibility of producing fine-grade cigar-wrapper under cheesecloth shade, but unfortunately, his findings did not attract the attention of the tobacco growers till 1929, when he and Tugade(4) demonstrated the method again in the Cagayan Valley and later introduced it in the Province of La Union where it is gaining a better foothold at present.

The experience of Paguirigan and Tugade during the past four years shows that the cost of producing one hectare of shade-grown wrapper amounts to a little over ₱900. The list of expenses and the estimated yield per hectare (15,873 plants, 90 cm. × 70 cm.) based upon their trial experiment at the Los Baños

Economic Garden, Los Baños, Laguna (1933–1934), are as follows:

TABLE 1.—*Cost of operation and estimated income per hectare per year.*

Items of operation.	Man.	Woman.	Animal.	Approximate cost.
	Days.	*Days.*	*Days.*	*Pesos.*
1. Buildings, equipment, and shading materials:				
(*a*) One curing shed (16 m. x 8 m. x 3 m.) of mixed materials				200.00
(*b*) 12,000 linear meters abacá cloth for tent cover worth ₱600 to last three years				200.00
(*c*) 400 long bamboos for shade frame worth ₱60 to last for three years				20.00
(*d*) 1,000 long palillos				20.00
(*e*) One steel balance				4.00
(*f*) One thermometer				1.50
2. Seed-bed operation:				
(*a*) 200 grams of seeds				1.00
(*b*) Preparation, sowing, and shading of the beds with an area of 1 m. x 10 m.	30		30	24.00
(*c*) Rearing of seedlings up to transplanting time, including weeding, dusting, watering, thinning, and arsenicals	10	30		17.00
3. Field operations:				
(*a*) Preparation of land, three plowings and three harrowings	12		12	14.00
(*b*) Erection of tent frame	50			50.00
(*c*) Transplanting	10	30		17.00
(*d*) Placing abacá cloth	150			120.00
(*e*) Cultivation, three times	8		8	9.60
(*f*) Worming, dusting, and arsenicals		96		28.80
(*g*) Harvesting		72		22.60
4. Barn operations:				
(*a*) Poling and stringing	24	120		55.20
(*b*) Curing-shed caretaker	16			12.80
(*c*) Bundling and fermentation	12	30		18.60
(*d*) Classification and rebundling	8	120		42.40
(*e*) Baling and baling materials	4			8.40
5. Incidentals				30.00
Total				917.30

Yield per hectare:

(*a*) 100 kilos at ₱3 a kilo	₱300.00	
(*b*) 500 kilos at ₱2 a kilo	1,000.00	
(*c*) 50 kilos at ₱1 a kilo	50.00	
(*d*) 100 kilos at ₱0.30 a kilo	30.00	
Total—750 kilos valued at	1,380.00	(gross income)
Total expenditures	917.30	
Net income	462.70	

As the itemized expenses and the estimated yield per hectare, as listed in Table 1, show a good margin of profit in raising cigar-wrapper under shade in the Philippines, an experiment was undertaken by the Tobacco Research Section at the Los Baños Economic Garden (1934–1935) with the object of deter-

mining (1) which of the three leading varieties for wrapper purposes we have in the Philippines is best adapted to shade conditions, (2) the best time to shade the plants, and (3) the nature of the environment of the shaded plants as compared with open-grown cultures. This experiment was carried out in three replicate cultures.

MATERIALS AND METHODS

Variety used.—Pricked tobacco seedlings (63 days old from sowing) of varieties Ilagan Sumatra, Simmaba, and Vizcaya were transplanted on the field at the Los Baños Economic Garden, Los Baños, Laguna, January 5, 1935. Ilagan Sumatra is a strain developed at Ilagan from an imported genuine Sumatra variety. When grown without shade it produces leaves of medium size and fair wrapper quality. The other two varieties used are of native origin. Simmaba, when grown without shade, produces leaves that are long and wide, but unsuitable as wrappers for high-grade cigars due to the coarseness of their veins and the thickness of their lamina. Vizcaya is very similar to Simmaba. It produces leaves as long as, but narrower than Simmaba (Plate 1).

Planting plan.—The three varieties of tobacco were planted three rows in each lot. There were 168 plants to a row. The rows were 90 cm. apart and the distance between the plants in a given row was 70 cm. The rows were laid East to West and divided crosswise into 7 lots. The lots were designated as A–4, B–5, C–6, D–7, E–8, F–9, and were not shaded (control). (The number following the letter indicates the number of weeks that had elapsed from the date of transplanting to the time when the abacá shade was placed, that is, Lot A–4, was shaded 4 weeks after transplanting, Lot B–5, 5 weeks after transplanting, etc.)

Shade.—The shelter tent was 9 feet high. The shading material was made of abacá fiber. The finished product is commercially called abacá cloth (10 threads to the inch). The first lot of each variety was shaded 4 weeks after transplanting. The other lots were shaded at weekly intervals following the first shading. The sides of the tent were made of the same material (Plate 2).

Weather observations.—Comparative measurements of air and soil temperature, relative humidity, and evaporation were taken under the shade tent and in the open culture during the entire growing period of the tobacco plants. Rainfall records for the same period were furnished by the Plant Physiology Depart-

ment of the College of Agriculture. (The Los Baños Economic Garden is 2.5 kilometers away from the College of Agriculture.)

The temperature of the air was taken daily, three times during the day, at 8 a. m., 12 noon, and 5 p. m. with the use of a thermometer graduated to 1 ° C. The temperature of the soil was also observed three times a day with the use of a soil thermometer.

The humidity of the air 3 feet from the soil surface was measured at 8 a. m., 12 noon, and 5 p. m. daily with tycos hygrometer.

Evaporation was determined by placing Livingston's standardized spherical porous cup atmometers 3 feet above the surface of the soil. The apparatus was provided with a non-absorbing device. Readings were taken weekly.

Field observation.—The height of each plant was taken when the inflorescence was fully exposed. The measurement was taken from the surface of the ground to the tip of the inflorescence. The circumference of the stem was measured at a height 30 cm. from the ground. The length and width of standard leaves were taken every time priming was done. The number and fresh weight of all leaves harvested from the different lots were recorded.

Materials for leaf-structure study.—When the first priming of standard leaves was done, sections of leaf samples for leaf-structure study of the three varieties were taken from all the different lots. The samples were cut at the middle on both sides of the lamina of representative standard leaves, and cut portions were immediately immersed in Formalin-Acetic-Alcohol (70 per cent) prepared according to a formula given by Chamberlain(1). They remained in the fixing fluid for 24 hours after which the usual histological method was followed. The sections were cut 10 microns thick and stained with Sudan III. The lower epidermis of the standard leaves was peeled off and plunged immediately into absolute alcohol. The stained sections and the peeled epidermis were drawn under camera lucida.

Curing and classification.—The leaves harvested were brought to the curing house and poled in the usual way. The sand leaves were separated from the rest of the leaves and poled separately. After curing, the dry weight was taken and the leaves were classified into three groups as sand leaves, standard leaves, and top leaves. At the time of first priming the first 3 or 4 leaves from the ground were usually over-matured and in some cases dry. They had no market value. These leaves were

considered as sand leaves. Standard leaves included all leaves (excluding sand leaves) as long as or longer than 30 cm. Leaves shorter than 30 cm. were classified as top leaves. When classification was finished, the number, average length and width, and weight of the standard leaves from each of the lots were noted. Also, the average diameter of the veins, and the thickness of the lamina, and the bursting strength of the leaf were determined. The diameters of all primary veins were determined and the thickness of the leaf taken at the middle on both sides of the leaf blade, half-way from the midrib, with the use of "Perkins micrometer dial gage" graduated to 1/1000 inch, and the bursting strength of the leaf was observed, with the use of the "Muller paper tester" graduated to one pound per square inch. Both instruments were manufactured by B. F. Perkins and Son Inc., Holyoke, Mass., U. S. A. For comparison, imported wrapper-leaf tobacco of varieties Sumatra and Georgia were also studied. The cost per kilogram of the locally grown wrapper and of imported Sumatra-wrapper leaf were ascertained by the Chief of the Tobacco Industry Section of the Bureau of Internal Revenue.

RESULTS

The results of this experiment are presented in tabulated forms and grouped into two; namely, climatic factors on the one hand and plant responses on the other.

Climatic factors.—Tables 2, 3, 4, 5, and 6 are comparative tables of weather factors taken on the same date both under the shade and in the open culture.

Table 7 is a summary of the climatic conditions that prevailed during the entire growing period of the tobacco plants, and the differences between records obtained under shade and in the open culture are expressed in percentages.

Plant responses.—Table 8 shows the relative vigor of the three varieties of tobacco used and the relative effect of time of shading upon height of plants, circumference of stems, total number of leaves, and date of flowering.

Table 9 is a comparative table showing the effect of the time of shading upon the length and width of standard leaves, the number and weight of sand, standard and top leaves, and the water content. The percentage of water content was based on fresh weight.

Table 10 is a direct comparison of imported wrapper-leaf tobacco with leaves produced locally but shaded at different times.

Table 11 is an estimate showing possible yield per hectare under the different conditions tried in the experiment.

TABLE 2.—*Average weekly air temperature at the Los Baños Economic Garden (1935).*

Date of observation.	Shaded.				Exposed (open culture).			
	8 a. m.	12 noon.	5 p. m.	Average.	8 a. m.	12 noon.	5 p. m.	Average.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Feb. 2–9	24.4	29.1	27.8	27.1	24.3	29.1	28.2	27.2
Feb. 10–16	25.4	28.4	26.1	26.6	25.0	29.8	26.4	27.1
Feb. 17–23	24.4	28.8	26.5	26.6	23.7	29.0	27.1	26.6
Feb. 24–Mar. 2	26.9	31.0	28.5	28.8	26.8	31.6	30.0	29.5
Mar. 3–9	25.1	28.3	28.4	27.3	24.4	28.8	27.2	26.8
Mar. 10–16	25.9	30.4	29.2	28.5	25.4	31.8	30.8	29.3
Mar. 17–23	27.5	32.4	30.8	30.2	28.2	34.0	30.9	31.0
Mar. 24–30	27.7	32.8	31.6	30.7	28.7	34.9	32.0	31.9
Mar. 31–April 6	27.4	32.6	30.7	30.2	27.0	34.6	30.9	30.8
April 7–13	28.1	32.5	31.7	30.8	29.0	33.0	32.0	31.3
April 14–20	28.7	33.4	31.9	31.3	29.9	34.7	30.9	31.8
April 21–27	29.6	33.8	33.6	32.3	30.5	35.3	33.1	32.9
April 28–May 4	29.2	32.8	29.8	30.6	29.8	34.0	29.8	31.2
Average	26.9	31.3	29.7	29.3	27.1	32.4	29.9	29.8

TABLE 3.—*Average weekly soil temperature at the Los Baños Economic Garden (1935).*

Period of observation.	Shaded.				Exposed (open culture).			
	8 a. m.	12 noon.	5 p. m.	Average.	8 a. m.	12 noon.	5 p. m.	Average.
	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
Feb. 2–9	24.1	25.4	26.1	25.2	25.0	26.4	27.2	26.2
Feb. 10–16	25.0	25.5	26.0	25.5	25.7	26.0	26.6	26.1
Feb. 17–23	25.1	25.1	25.6	25.3	25.6	26.1	27.0	26.2
Feb. 24–Mar. 2	25.0	25.4	25.9	25.4	26.3	27.1	28.1	27.2
Mar. 3–9	25.3	25.4	25.7	25.5	26.6	27.1	28.0	27.2
Mar. 10–16	25.2	25.2	26.1	25.5	26.8	27.7	29.2	27.9
Mar. 17–23	26.5	26.8	29.2	27.5	28.1	30.1	31.6	29.9
Mar. 24–30	26.4	27.0	29.7	27.7	28.8	30.5	31.7	30.3
Mar. 31–April 6	26.9	27.5	28.6	27.7	29.5	31.4	32.5	31.1
April 7–13	26.7	27.1	28.2	27.3	28.7	30.6	31.9	30.4
April 14–20	27.1	27.7	28.9	27.9	29.8	31.9	33.3	31.7
April 21–27	29.5	28.7	30.0	29.4	31.1	33.9	34.0	33.0
April 28–May 4	27.9	28.7	29.1	28.6	30.0	33.0	33.4	32.1
Average	26.2	26.6	27.6	26.8	27.8	29.4	30.3	29.2

TABLE 4.—*Average weekly relative humidity at the Los Baños Economic Garden (1935).*

Date of observation.	Shaded.				Exposed (open culture).			
	8 a. m.	12 noon.	5 p. m.	Average.	8 a. m.	12 noon.	5 p. m.	Average.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Feb. 2–9	80.8	64.8	61.0	68.9	77.0	60.8	60.5	66.1
Feb. 10–16	82.0	69.3	73.8	75.0	80.8	59.3	70.3	70.1
Feb. 17–23	80.3	66.4	75.4	74.0	79.2	64.0	74.2	72.5
Feb. 24–Mar. 2	80.5	58.0	63.3	67.3	80.0	57.3	60.5	65.9
Mar. 3–9	80.6	64.0	64.5	69.7	79.5	63.3	63.6	65.5
Mar. 10–16	81.3	56.1	62.8	66.7	80.0	54.8	61.3	65.4
Mar. 17–23	77.1	58.8	54.8	63.6	75.3	55.5	53.6	61.5
Mar. 24–30	78.3	50.8	46.8	58.6	72.3	44.8	44.1	53.7
Mar. 31–April 6	76.3	55.0	57.1	62.8	75.1	52.8	55.3	61.1
April 7–13	74.8	58.8	59.7	64.4	71.0	56.1	54.3	60.5
April 14–20	69.5	55.2	57.0	60.6	67.5	51.2	44.0	54.2
April 21–27	70.5	53.3	52.5	58.8	66.0	48.3	50.3	54.8
April 28–May 4	79.2	73.6	83.4	78.7	78.4	71.0	82.0	77.1
Average	77.8	60.3	62.5	66.9	75.4	56.6	59.5	63.8

TABLE 5.—*Average weekly evaporation*[a] *at the Los Baños Economic Garden (1935).*

Date of observation.	Shaded.	Exposed.	Difference.
	c. c.	*c. c.*	*c. c.*
Feb. 2–9	139.8	197.8	58.0
Feb. 10–16	90.0	144.0	54.0
Feb. 17–23	98.6	147.8	49.2
Feb. 24–Mar. 2	114.6	166.3	51.7
Mar. 3–9	124.3	175.8	51.5
Mar. 10–16	151.1	209.7	58.6
Mar. 17–23	139.3	196.3	57.0
Mar. 24–30	165.7	232.1	66.4
Mar. 31–April 6	170.8	242.0	71.2
April 7–13	131.7	189.8	58.1
April 14–20	198.0	256.3	58.3
April 21–27	221.0	284.4	63.4
April 28–May 4	125.4	176.2	50.8
Daily average	20.5	28.8	8.3

[a] Livingston's white spherical atmometers were used.

TABLE 6.—*Daily rainfall at the College of Agriculture,*[a] *Los Baños (1935).*

Date.	January.	February.	March.	April.	May.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*
1	4.06				
2					
3	1.02				
4					
5					
6			2.54	11.94	
7				9.14	
8					
9		33.02			
10					
11	Trace				
12					
13					
14					
15		2.54			
16	2.03	1.27			
17	.25	1.27			
18					
19	2.04	2.03			
20		3.81			
21					
22	4.06				
23	6.60	.76			
24	7.62	1.27			
25	2.03	3.05			
26					
27					
28					
29				3.81	
30					
31					
Total	29.71	49.02	2.54	24.89	

[a] The College of Agriculture is 2.5 Km. from the Los Baños Economic Garden.

TABLE 7.—*A summary of weather records obtained under shade of abacá cloth and under direct sunlight at the Los Baños Economic Garden (1935).*

Elements and time of observation.	Shaded.	Open culture.	Plus or minus difference.
Air temperature:			*Per cent.*
8:00 a. m. °C	26.9	27.1	— 0.7
12:00 noon °C	31.3	32.4	— 3.5
5:00 p. m. °C	29.7	29.9	— 0.7
Average	29.3	29.8	— 1.7
Soil temperature:			
8:00 a. m. °C	26.2	27.8	— 6.2
12:00 noon °C	26.6	29.4	—10.6
5:00 p. m. °C	27.6	30.3	— 9.8
Average	26.8	29.2	— 8.9
Relative humidity:			
8:00 a. m. per cent	77.8	75.4	+ 3.0
12:00 noon per cent	60.3	56.6	+ 6.1
5:00 p. m. per cent	62.5	59.5	+ 4.8
Average, per cent	66.9	63.8	+ 4.6
Evaporation per day cc.	20.5	28.8	—28.8

Rainfall:	*mm.*
January	29.71
February	49.02
March	2.54
April	24.89
Total	106.16

TABLE 8.—*Field data and harvest records of 20 tobacco plants shaded at different intervals.*[a]

Variety and Lot No.	Average height.	Average circumference of stem.	Average measurement of fresh standard leaves.		Total number of leaves of 20 plants.			Total weight of fresh leaves of 20 plants.			
			Length.	Width.	Sand.	Standard and top.	Total.	Sand.	Standard and top.	Total.	Date of flowering.
Ilagan Sumatra:	*cm.*	*cm.*	*cm.*	*cm.*				*gms.*	*gms.*	*gms.*	
A–4	227.8	5.2	44.0	26.8	60	455	515	1020	6091	7111	3–22–35
B–5	224.9	5.7			59	465	524	1109	7055	8164	3–19–35
C–6	209.0	5.8	44.8	27.9	62	464	526	1262	7969	9231	3–14–35
D–7	200.4	5.9			60	462	522	1290	7981	9271	3–14–35
E–8	197.6	5.9			75	449	527	1627	7981	9608	3– 9–35
F–9	190.0	5.9			80	441	521	1668	7986	9654	3– 6–35
Not shaded	180.6	6.3	43.5	27.0	80	450	530	1676	8090	9766	3– 6–35
Simmaba:											
A–4	249.3	6.2	52.0	24.4	62	621	683	1056	8929	9985	4– 7–35
B–5	245.3	6.6			70	623	693	1200	9500	10700	3–27–35
C–6	235.0	6.6	58.0	27.8	72	626	698	1380	10170	11550	3–23–35
D–7	229.7	6.8			76	607	683	1400	11250	12650	3–23–35
E–8	218.2	6.9			79	604	683	1428	11592	13020	3–19–35
F–9	207.0	7.0			82	612	694	1525	11895	13420	3–19–35
Not shaded	201.2	7.2	56.3	24.9	84	606	690	1575	12275	13850	3–15–35
Vizcaya:											
A–4	237.0	6.0	50.2	22.5	61	618	679	1024	8022	9046	4– 7–35
B–5	227.6	6.5			70	622	692	1190	9330	10520	4–27–35
C–6	214.9	6.8	58.1	25.6	73	627	700	1277	9345	10622	3–23–35
D–7	210.9	6.7			75	604	679	1350	10019	11362	3–23–35
E–8	206.1	7.0			80	610	690	1440	10286	11726	3–19–35
F–9	203.0	7.2			83	612	695	1527	10280	11807	3–19–35
Not shaded	192.1	7.4	53.4	23.1	84	603	687	1528	10325	11853	3–15–35

[a] Figures are averages of three replicate cultures of 20 plants each.

TABLE 9.—*Harvest data of leaves of 20 tobacco plants after curing.*

Variety and Lot No.	Average measurement of cured standard leaves.		Total number and cured weight of leaves of 20 plants.							Total weight.	Water content. [c]
			Sand.		Standard. [a]			Top. [b]			
	Length.	Width.	Number.	Weight.	Number.	Weight.	Average weight per leaf.	Number.	Weight.		
Ilagan Sumatra:	*cm.*	*cm.*		*gms.*		*gms.*	*gms.*		*gms.*	*gms.*	*Per cent.*
A–4	36.60±.339	20.48±.281	60	120	230	575	2.50	225	135	830	88
B–5	40.36±.406	22.24±.261	59	124	245	715	2.92	220	154	993	88
C–6	40.92±.356	22.48±.250	62	161	258	849	3.29	206	164	1176	87
D–7	40.76±.288	22.42±.256	60	162	242	822	3.39	220	176	1160	88
E–8	40.30±.403	21.96±.376	75	217	222	819	3.69	227	204	1242	87
F–9	40.00±.404	21.48±.303	80	248	205	820	4.00	236	228	1296	86
Not shaded	39.90±.317	21.40±.332	80	256	200	800	4.00	250	244	1300	87
Simmaba:											
A–4	43.24±.275	17.00±.172	62	124	321	870	2.89	300	174	1168	88
B–5	46.00±.387	22.76±.269	70	161	342	1122	3.28	281	184	1467	86
C–6	49.88±.389	24.04±.265	72	187	343	1175	3.43	283	210	1572	85
D–7	49.84±.46	23.90±.229	76	220	306	1275	4.17	301	255	1750	86
E–8	48.44±.441	22.60±.273	79	244	300	1275	4.25	304	281	1800	86
F–9	45.32±.46	22.00±.239	82	262	270	1239	4.59	342	316	1817	87
Not shaded	43.72±.349	21.72±.185	84	277	261	1220	4.68	345	338	1835	88
Vizcaya:											
A–4	44.36±.279	16.10±.118	61	122	332	880	2.65	305	181	1183	87
B–5	48.12±.363	20.92±.242	70	160	344	1063	3.09	278	172	1395	87
C–6	49.54±.549	22.44±.277	73	168	337	1085	3.22	290	191	1444	86
D–7	49.44±.246	22.36±.218	75	217	304	1192	3.92	300	241	1650	86
E–8	47.56±.404	21.72±.148	80	256	300	1175	3.92	310	255	1686	86
F–9	44.52±.406	20.76±.074	83	274	272	1156	4.25	340	304	1734	87
Not shaded	43.76±.345	20.52±.176	84	275	253	1181	4.58	350	341	1797	85

[a] Leaves shorter than 30.0 cm. were not included.
[b] All leaves shorter than 30.0 cm. were classified as top leaves.
[c] Water content was based on fresh weight.

TABLE 10.—*The quality and cost per kilogram of tobacco leaves produced by shading at different lengths of time compared with imported leaf-tobacco wrappers, Sumatra and Georgia varieties.*

Variety and criteria.	Number of weeks elapsed between transplanting and shading.						Plants not shaded.	Imported wrappers.	
	4	5	6	7	8	9		Sumatra.	Georgia.
ILAGAN SUMATRA									
Average length of cured leaves, cm.	36.60±.339	40.36±.406	40.92±.356	40.76±.288	40.30±.403	40.00±.404	39.90±.317	39.58±.162	41.80±.606
Average width of cured standard leaves, cm.	20.48±.286	22.24±.261	22.48±.250	22.42±.256	21.96±.376	21.48±.303	21.4 ±.332	20.86±.218	21.20±.580
Average diameter of veins of cured standard leaves, mm.	0.29±.004	0.33±.004	0.39±.006	0.42±.005	0.42±.006	0.42±.008	0.43±.005	0.32±.007	0.38±.004
Average thickness of lamina of cured standard leaves, microns	33 ±0.7	38 ±1.0	42 ±1.0	44 ±1.0	54 ±0.5	68 ±1.0	73 ±.0.9	38 ±1.2	39 ±1.2
Average bursting strength of cured standard leaves, lbs./sq. in.	5.73±.069	6.28±.055	6.38±.081	6.36±.052	6.38±.081	6.50±.081	6.76±.081	6.26±.081	4.5 ±.149
Cost per kilogram, pesos	2.50	3.00	2.00	1.50	1.50	1.00	0.60	6 to 14	
SIMMABA									
Average length of cured standard leaves, cm.	43.24±.275	46.00±.387	49.88±.389	49.84±.46	48.44±.441	45.32±.460	43.72±.349	39.58±.162	41.80±.606
Average width of cured standard leaves, cm.	17.00±.179	22.76±.269	24.04±.265	23.90±.229	22.60±.273	22.00±.239	21.72±.185	20.86±.218	21.20±.580
Average diameter of veins of cured standard leaves, mm.	0.29±.005	0.31±.006	0.35±.005	0.36±.006	0.39±.006	0.43±.007	0.50±.008	0.32±.007	0.38±.004
Average thickness of lamina of cured standard leaves, microns	36 ±0.7	38 ±1.0	51 ±1.4	58 ±1.3	62 ±.09	79 ±1.0	95 ±1.3	38 ±1.2	39 ±1.2

Average bursting strength of cured standard leaves, lbs./sq. in.	6.4 ±.075	6.42±.066	6.62±.068	6.70±.058	6.70±.059	6.8 ±.051	7.00±.068	6.26±.081	4.50±.149
Cost per kilogram, pesos	2.00	2.50	1.50	1.00	1.00	0.70	0.40	6 to 14	
VIZCAYA									
Average length of cured standard leaves, cm.	44.36±.279	48.12±.363	49.54±.549	49.44±.246	47.56±.404	44.52±.406	43.76±.345	39.58±.162	41.80±.606
Average width of cured standard leaves, cm.	16.10±.118	20.92±.242	22.44±.277	22.36±.218	21.72±.148	20.76±.074	20.52±.176	20.86±.218	21.20±.580
Average diameter of veins of cured standard leaves, mm.	0.30±.004	0.32±.004	0.37±.005	0.38±.006	0.40±.006	0.45±.008	0.58±.009	0.32±.007	0.38±.004
Average thickness of lamina of cured standard leaves, microns	38 +0.6	39 ±0.7	54 ±.09	56 ±1.1	66 ±1.1	81 ±0.7	99 ±1.4	38 ±1.2	39 ±1.2
Average bursting strength of cured standard leaves lbs /sq. in.	5.98±.102	6.52±.089	6.69±.105	6.85±.133	6.91±.105	7.01±.177	7.15±.107	6.26±.081	4.5 ±.149
Cost per kilogram, pesos	2.00	2.50	1.50	1.00	1.00	0.60	0.40	6 to 14	

TABLE 11.—*Computed yield (leaves not fermented) per hectare.*

Variety and Lot No.	Total yield.[1]	Marketable standard leaves.	Sand and top leaves.	Ratio—standard leaves:total yield.	Price per kilogram (standard leaves).	Total value.
Ilagan Sumatra:	*Kg.*	*Kg.*	*Kg.*		*Pesos*	*Pesos*
A–4	658.7	456.3	202.4	0.69	2.50	1,140.75
B–5	788.0	567.4	220.6	0.72	3.00	1,702.20
C–6	933.3	673.8	259.5	0.72	2.00	1,347.60
D–7	920.6	652.4	268.2	0.71	1.50	978.60
E–8	985.7	650.0	335.7	0.66	1.50	975.00
F–9	1028.6	650.8	377.8	0.63	1.00	650.80
Not shaded	1031.7	634.9	396.8	0.62	.60	380.40
Simmaba:						
A–4	927.0	690.5	236.5	0.74	2.00	1,381.00
B–5	1164.3	890.5	273.8	0.77	2.50	2,226.25
C–6	1247.6	932.5	315.1	0.75	1.50	1,398.75
D–7	1388.9	1011.9	377.0	0.73	1.00	1,011.90
E–8	1428.6	1011.9	416.7	0.70	1.00	1,011.90
F–9	1442.1	983.7	458.4	0.68	.70	688.59
Not shaded	1456.3	968.2	488.1	0.66	.40	387.28
Vizcaya:						
A–4	938.9	698.4	240.5	0.74	2.00	1,396.80
B–5	1107.1	843.6	263.5	0.76	2.50	2,109.00
C–6	1146.0	861.1	284.9	0.75	1.50	1,291.65
D–7	1309.5	946.0	363.5	0.72	1.00	946.00
E–8	1338.1	932.5	405.6	0.70	1.00	932.50
F–9	1376.2	917.5	458.7	0.67	.60	550.50
Not shaded	1426.2	937.3	488.9	0.66	.40	374.92

[1] Figures for total yield were derived from Table 9 (90 x 70 cm.).

DISCUSSION OF RESULTS

ENVIRONMENT

The weather records presented in Tables 2, 3, 4, 5, and 6, and the graphs in Plate 3 show that the tobacco plants shaded with abacá cloth were grown under a more mesic condition than those of the open cultures (not shaded).

Temperature.—The temperature of the air at 8 a. m., 12 noon, and 5 p. m. under the abacá shade during a period of 91 days averaged 26.9, 31.3, and 29.7° C., respectively. In the open culture (not shaded) the average air temperature for the same period was 27.1° C. in the morning, 32.4° C. at noon, and 29.9° C. in the afternoon. The day average air temperature under abacá cloth was 29.3° C. and that of the open culture, 29.8° C. Although the difference in temperature was small, the temperature of the air surrounding the open-grown cultures was almost in all cases higher than the air temperature under the shade (Plate 3).

The temperature of the soil under the shade was lower than the temperature of the soil in the open (Plate 3). Under the shade, the day average soil temperature was 26.8° C. and the temperature of the soil in the open culture was 29.2° C. In both cases, under the shade and open culture, the temperature of the soil was highest in the afternoon and lowest in the morning (Table 7). It is unlike that of air temperature in which the maximum reading was obtained during the middle part of the day. The average maximum temperature of the soil under the shade was even lower than the average minimum temperature of the soil in the open culture (Table 7). The readings were 27.6° C. for the former and 27.8° C. for the latter. The day average temperature of the soil under the shade was 8.9 per cent lower than the temperature of the soil in the open culture.

Humidity of the air.—The relative humidity of the air under the shade was in all periods of observation higher than the relative humidity of the air in the open culture. The humidity of the air at 8 a. m. under the shade averaged 77.8 per cent while that of the open culture was 75.4. At the middle of the day and at 5 o'clock in the afternoon the relative humidity readings were 60.3 and 62.5 per cent, respectively, for the shade and 56.6 and 59.5 per cent, respectively, for the open-culture (Table 7). The greatest difference occurred during the middle of the day when the relative humidity of the air under the shade was 6.1 per cent higher than the humidity of the air in the open culture.

Rainfall.—There was sufficient moisture in the soil during the vegetative growth period of the tobacco plants. A total of 106.16 mm. of rain fell from January 1st to May 4th, and was distributed as follows: There were 9 rainy days in January and the total rainfall for that month was 29.71 mm. In February, it rained 9 times also and the total precipitation was 49.02 mm. It rained once in March, the precipitation amounting 2.54 mm. and three times more in April, totalling 24.89 mm. (Table 6).

THE PLANT

Effect of shade upon maturity.—Shade delays flowering of tobacco plants. The figures presented in Table 8 reveal the fact that the earlier the plants were shaded the longer was the delay of flowering. Ilagan Sumatra, shaded 4 weeks after transplanting, flowered 16 days later than the plants not shaded, and those shaded 5 weeks after transplanting flowered 13 days later.

Simmaba and Vizcaya, which are late maturing varieties, when shaded 4 weeks after transplanting, flowered 22 days later than those which were not shaded. And plants, shaded 6 weeks after transplanting, flowered 14 days earlier than those shaded 4 weeks after transplanting. There appeared to be a direct correlation between earliness of flowering and earliness of shading (Table 8).

Effect of shade upon the stature of the tobacco plant.—Abacá cloth with 10 threads to the inch, gave sufficient shade to effect a change in the aërial environment to modify the stature of the plant. The shaded plants were taller than the unshaded ones, and those in Lot A–4 were the tallest in the shaded cultures. There was direct correlation between tallness and earliness of shading. The younger the plant when shaded the taller it grew, but the stems were slender. Ilagan Sumatra, shaded 4 weeks after transplanting, were 20 per cent taller than the unshaded ones. Simmaba and Vizcaya varieties, when shaded 4 weeks after transplanting, were both 23 per cent taller than those that were not shaded. The internodes of the shaded plants were longer than those grown in the open-culture. This is in accord with the results of Weaver and Clements who stated that the "stems of plant grown in shade are regularly taller and often more branched than corresponding sun forms." The plants under the shade, besides being taller, were also slenderer than the sun plants. The circumference of the stem about a foot from the ground was on the average 16 per cent less than that of the stem grown in the open.

Effect of shade upon the size, number, and weight of leaves.—Shading tobacco plants does not always tend to develop long and wide leaves. Actually, early shading inhibits the growth of tobacco leaves. The tobacco plants, shaded 4 weeks after transplanting had short and narrow leaves. They were even smaller than the leaves of the unshaded plants. But the leaves of plants shaded 5 weeks after transplanting were large and the leaves of plants shaded 6 weeks after transplanting (Lot C–6) were still larger (Table 9). Leaves of lots D–7, E–8, and F–9 were smaller than leaves of Lot C–6 but longer and wider than the leaves of the unshaded plants.

Shading the plant with abacá cloth did not influence the production of more leaves per plant, but a big difference in the amount of dry weight produced per leaf of the standard leaves was observed. The weight of shaded leaves was less than the weight of leaves of open-grown cultures. There was a gradual

decrease of dry weight per leaf as the number of weeks under shade was increased. Plants shaded within the shortest period prior to harvesting had the greatest weight per leaf and plants shaded the longest time had the least dry weight (Table 9). Tobacco leaves contain about 87 per cent water (fresh weight).

Effect of shade upon yield.—Among the three varieties studied, Simmaba had the greatest yield, Vizcaya second greatest, and Ilagan Sumatra the least. Shading decreased the total yield (total yield includes sand, standard, and top leaves). Table 11 shows that the lots shaded the longest had the least total yield and those shaded the shortest time had the greatest yields. Separating sand and top leaves from the total yield, leaving only marketable standard leaves, Ilagan Sumatra, shaded 6 weeks after transplanting, and Lot D–7 of Simmaba and Vizcaya, produced the heaviest marketable leaves. Open-grown cultures had more sand and top leaves than any of the shaded cultures, due to the fact that there were more leaves of the open-grown cultures less than 30 cm. long than among those of the shaded plant (Table 11). It can be seen from Table 11 that the ratio of marketable standard leaves to total yield of Ilagan Sumatra was highest in Lot B–5, being 0.72, and lowest in the not shaded cultures which was only 0.62. The closer the ratio to unity the greater was the weight of marketable standard leaves and vice versa. This result is not only true with Ilagan Sumatra, but was also confirmed by the harvest made from Simmaba and Vizcaya varieties.

Imported wrapper-leaf tobacco compared with leaves of open-grown cultures of Ilagan Sumatra, Simmaba, and Vizcaya.—Good cigar-wrapper should be uniform in color, elastic, thin, and with fine veins. The imported Sumatra wrapper-leaf tobacco is famous for the fineness of its veins and the thinness of the leaf, qualities that are also possessed by Georgia cigar-wrappers. For these reasons the quality of open-grown tobacco leaves in the Philippines was compared with that of these accepted standard cigar-wrapper varieties, Sumatra and Georgia. The imported Sumatra wrapper, used as a basis for comparison, was graded by the Chief of Tobacco Industrial Section of the Bureau of Internal Revenue as of superior quality, fine-textured, and valued at ₱8 a kilogram. The price of imported Sumatra wrappers ranges from ₱6 to ₱14 a kilogram.

Under open conditions (not shaded) the leaves of Ilagan Sumatra were longer than Sumatra leaves but shorter than the leaves of the Georgia variety. However, the width of the Ilagan

Sumatra leaf was greater than that of the two imported standards. Simmaba leaves were longer and wider than the leaves of Sumatra or Georgia. The leaves of Vizcaya on the other hand, although as long as the leaves of Simmaba, were narrower than the leaves of either the Sumatra or Georgia variety (Table 10).

The dried leaves of the Ilagan Sumatra, Simmaba, and Vizcaya were thick and the veins coarse. The diameter of the veins of the leaves of Ilagan Sumatra averaged 0.43 mm., while those of Sumatra and Georgia were 0.32 and 0.38 mm., respectively. Ilagan Sumatra leaves averaged 73 microns in thickness and Sumatra and Georgia 38 and 39 microns, respectively. In other words, the leaves of open-grown Ilagan Sumatra leaves in the Philippines were 48 per cent thicker and the veins 26 per cent coarser than the imported Sumatra leaves. The other two varieties, Simmaba and Vizcaya, were inferior as wrappers to Ilagan Sumatra. Leaves of open-grown cultures of these three varietties were inferior to imported Sumatra and Georgia cigar wrappers.

Effect of shade upon the form and structure of the tobacco leaf.—The plants shaded 4 weeks after transplanting had on the average small and narrow leaves in proportion to the length of the leaf. Those that were shaded a week later had longer and wider leaves, and the leaves of plants shaded 6 weeks after transplanting had the longest and widest leaves. Leaves of plants shaded 7 weeks after transplanting were smaller than the leaves of plants in Lot C–6 but still bigger than the leaves of the unshaded cultures. It is apparent, therefore, that shading of tobacco plants 5 weeks after transplanting favored the production of long, broad, and thin leaves; but the growth of the leaves was inhibited when the plants were shaded as early as 4 weeks after transplanting.

Shade modifies not only the size of the tobacco leaf but also its structure. Plate 4 shows plainly that the leaves of plants shaded when but 4 weeks old on the field, specially those of Ilagan Sumatra variety, did not develop palisade cells. Simmaba and Vizcaya barely showed the beginning of palisade cell formation. The leaves were thin and the veins fine. These leaves possessed characteristics of a type commonly known as "shade leaves." The plants shaded 7 weeks after transplanting had leaves almost as thick as the leaves of unshaded plants. The leaves were, however, developed more feebly than the leaves of the open-grown cultures (Plate 4).

The open-grown cultures, specially those of Simmaba and Vizcaya, had very thick leaves. The epidermis was thick and the cuticle was highly cutinized. Beneath the epidermis there was a layer of well-developed palisade cells. The mesophyl tissue was provided with plenty of air spaces but not as loosely arranged as the tissue of the plants shaded 4 or 5 weeks after transplanting. The plants shaded earliest (Lot A–4) were feebly cutinized and in some cases cutinization was absent. There was an apparent increase in the size of stomata when the plants were shaded but there appeared to be a reduction in the number per unit area (Plate 4).

Effect of shade upon the quality of leaves as cigar-wrapper.— Sumatra wrapper is admitted by all leading cigar manufacturers to be the best. The Cubans even admit the superiority of Sumatra wrappers notwithstanding the high reputation of their famous wrapper. The outstanding high qualities of Sumatra wrapper are: color, high degree of elasticity, thinness of lamina, and fineness of veins.

The results of this experiment show that we can produce wrapper-leaf tobacco in the Philippines as good as the Sumatra wrappers, if not better, by shading tobacco plants at a certain age. The graphs in Plate 5 shown this fact very clearly.

Although color is one of the essential qualities of high-grade wrappers, this factor is not considered a problem in the Philippines. The leaves of our native tobacco varieties, when harvested at the right age and cured properly, develop color comparable to that of the color of imported Sumatra wrappers. The great drawbacks of our open-grown wrappers lie in the thickness of the leaf and in the coarseness of the veins.

Considering the thinness of the lamina and the fineness of the veins as the first two requisite factors essential to good wrappers, the results thus far obtained show that the varieties Ilagan Sumatra, Simmaba, and Vizcaya, when shaded at the proper time, developed leaves equal to if not better than the famous Sumatra, wrapper. With no exception, when the plants were shaded 4 weeks after planting (Lot A–4), the standard leaves were thinner and the veins were finer than those of the imported Sumatra wrapper. And, in the plants shaded 5 weeks after transplanting, the leaves were almost, if not quite, as thin as the accepted standard cigar-wrappers (Table 10 and Plate 5).

Plants shaded as late as 6 weeks after transplanting did not produce leaves as thin as those of Lot B–5 (shaded 5 weeks after transplanting); however, the produce obtained was still far

better than that of the unshaded leaves. Plate 5 further shows that lines for thinness and coarseness of veins and even the breaking strength of the lamina of the leaf shaded 4 weeks after transplanting were lower than line XY, the standard. This means that leaves in Lot A–4 were thinner and had finer veins than the standard Sumatra wrapper but had a weaker bursting strength value. These lines intersect line XY at the neighborhood of point B–5. This shows that, when the plants were shaded 5 weeks after transplanting, the thinness of the leaf and the fineness of the veins were equal to, or almost the same as those of the standard wrapper-leaves. The bursting strength of the leaves shaded 5 weeks after transplanting was even a little higher than that of the standard wrapper-leaves. Beginning from Lot B–5, the graphs for thickness of leaf, coarseness of vein, and bursting strength were all above line XY. This trend of the graphs shows the inadvisability of placing shade over the plants as late as 6 weeks after transplanting.

YIELD, COST OF PRODUCTION, AND MARKET VALUE

Yield per hectare.—The plants were spaced 90 cm. between the rows and 70 cm. between the plants. On a hectare basis there would be 15,873 plants. Considering the harvest obtained from the yield of 20 representative plants of three replicate cultures as shown in Table 9, we could have a very fair estimate of the yield per hectare.

The computed yield per hectare (leaves not fermented) as presented in Table 11 shows that of the three varieties of the tobacco studied, Simmaba yielded the heaviest, Vizcaya the second heaviest, and Ilagan Sumatra the least. Comparing the yield obtained from shaded and unshaded cultures, the figures plainly indicate that the shaded cultures produced less total yield (sand, standard, and top leaves taken together) than the unshaded plants. There was a steady increase in total yield as the placing of shade after transplanting was delayed longer and longer. Shading the plants as early as 4 weeks after transplanting effected a loss of 36 per cent for Ilagan Sumatra, 36 per cent for Simmaba, and 34 per cent for Vizcaya. But this percentage of loss in total yield steadily decreased as more weeks elapsed after transplanting before the plants were shaded, that is, the plants shaded 9 weeks after transplanting incurred the least loss in total yield. The weight of marketable standard leaves (Table 11) shows that a higher yield was obtained from some of the shaded cultures than from the unshaded ones. The heaviest

yield for Ilagan Sumatra was obtained when the plants were shaded 6 weeks after transplanting and the next heaviest was when they were shaded 7 weeks after transplanting. Of the late maturing varieties, Simmaba and Vizcaya, when shaded 7 weeks after transplanting, produced the heaviest marketable standard leaves. It is obvious, therefore, that there were more sand and top leaves produced in the open-grown cultures than by the shaded plants. Table 11 shows this fact clearly. In the case of Ilagan Sumatra, 72 per cent of the total yield was marketable when the plants were shaded 5 to 6 weeks after transplanting and only 62 per cent of the total yield was marketable when the plants were not shaded. In the other two varieties, Simmaba and Vizcaya, when shaded 6 weeks after transplanting, 75 per cent each of the total yield was marketable.

Cost of production per hectare.—The cost of production of wrapper-leaf tobacco varies a great deal, depending upon methods, material, and the country where the plant is grown. According to Paguirigan and Tugade, the cost of production per hectare is as follows:

1. Sumatra—sun-grown, cultivated by banking—net cost per hectare	₱1,385.00
2. Cuba—shade-grown, by using cheesecloth—net cost per hectare	1,940.00
3. United States—Connecticut Valley shade-grown, using cheesecloth—net cost per hectare	2,067.94
4. Philippine Islands—shade-grown, using bamboo and palm leaves as shade—net cost per hectare	804.00
5. Philippine Islands—shade-grown, using abacá cloth as shade—net cost per hectare	917.30

It is apparent from the above figures that the initial cost of the production of cigar wrapper is high. United States tops the list and the Philippine Islands is at the bottom. There is, therefore, a big chance for commercial competition in favor of the Philippines in the raising of leaf-tobacco wrappers.

Market value.—The price of shade-grown wrapper in the Philippines is very low as compared with imported leaf-tobacco wrappers. Yet the quality of our shade-grown leaf-tobacco wrappers compares favorably with that of imported cigar wrappers (Table 10). Of the former, the price per kilogram of the best quality is ₱3,[a] whereas the price of the latter oscillates between ₱6 and ₱14.

[a] Appraised by the Chief of the Tobacco Industry Section, Bureau of Internal Revenue.

The marketable standard leaves obtained from plants shaded 5 weeks after transplanting were valued highest by the Chief of the Tobacco Industry Section of the Bureau of Internal Revenue (Table 11). The leaves of plants shaded 4 weeks after transplanting were ranked close second, and those shaded 6 weeks after transplanting were placed third.

Considering the total value of standard leaves that can be produced on one hectare, Simmaba variety, if shaded 5 weeks after transplanting, would give ₱2,226.25; Vizcaya, ₱2,109; and Ilagan Sumatra, ₱1,702.20. If the cost of operation per hectare as shown under cost of production is deducted from the gross profit, there is still a big margin of gain, so that if we allow 50 per cent loss to cover damages incurred in the field, in the curing house, transportation, bargaining of prices, and some overhead expenses, there would remain a gain (for Simmaba variety) of not less than ₱600.

THE NATURE OF AËRIAL ENVIRONMENT OF TOBACCO PLANTS UNDER ABACÁ CLOTH

The chief factors of the aërial environment of plants are light, humidity, temperature, and wind. In the soil the important factor is water.

The records of the environmental factors taken separately during the growing period of the tobacco plants under abacá shade and in the open-grown culture show constant, and in some cases, very distinct differences (Table 7). According to Weaver and Clements (6) the evaporating power of the air when measured directly gives the integrated effect of humidity, radian energy (i. e., temperature and light), and wind. While there is no instrument that integrates the effect of these different stimuli to water loss in a manner similar to that of plants, this objective has been attained to some extent with the use of Livingston's standard spherical atmometers when placed at the general level of the transpiring vegetation in different habitats. The average records of water loss per day from white atmometers were 20.5 cc. under abacá shade and 28.8 cc. in the open culture (not shaded). This means that the evaporating power of the air under the abacá shade was 28.8 per cent less than in the open culture. Inasmuch as the rate of transpiration (up to a certain limit) is directly proportional to the evaporating power of the air, it is obvious that the plants in the open culture were transpiring about 28 per cent higher than those plants under the shade. This difference in water loss due to difference

in environment resulted to a modification in the form and structure of the leaf. The shaded leaves were broad and thin and the leaves of the plants in the open cultures were small and thick. This material change of structure of the leaf from small and thick to broad and thin was brought about with the use of abacá cloth. The shade cut off a great deal of the intensity of sunlight, reduced the velocity of the wind to a very low rate, maintained low soil and air temperatures, the humidity of the air was kept rather moist, and, lastly, the loss of water content of the soil was minimized. These conditions were not favorable for rapid transpiration. It is apparent, therefore, that not the evenness of the distribution of rainfall throughout the growing period of the tobacco plant was responsible for the production of fine-grade cigar-wrappers, as is claimed to be the case at Medan, Sumatra, but was the aggregate effect of aërial environmental factors not favorable for rapid transpiration. If it had been due to rainfall then the plants grown in the open culture would have had leaves as fine as those under the abacá shade, inasmuch as those plants were grown side by side with the shaded plants (Table 7 and Plate 5).

CONCLUSIONS

1. High grade leaf-tobacco wrappers comparable to imported Sumatra wrappers can be produced under abacá-cloth shade in the Philippines, particularly at Los Baños, Laguna.

2. Although the cost of production of shade-grown wrappers per hectare amounts to about ₱900, (under normal climatic conditions) a gain of not less than ₱600 can be realized.

3. The highest profit can be obtained by shading Simmaba variety. Under normal conditions, the highest yield can be obtained by shading tobacco plants 5 weeks after transplanting, that is, when the plants are knee high. Shading the plants later than 6 weeks after transplanting is a waste of effort.

RECOMMENDATIONS

The production of fine-grade leaf-tobacco wrappers under abacá shade is a proven fact, but the planting of tobacco plants under coconut trees is not recommended. Shade-grown wrapper production is expensive. Efforts should not, therefore, diminish in locating a region wherein we can raise high-grade cigar-wrapper under open conditions.

The meteorological data observed under the abacá shade and in the open cultures show that rainfall frequency is not a safe

criterion in the location of the ideal region for growing wrapper under open conditions. Knowledge of the evaporating power of the air should receive first consideration. Rainfall frequency comes next.

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ILLUSTRATIONS

PLATE 1

Typical plants of variety Simmaba (left), Ilagan-Sumatra and Vizcaya (right), Los Baños Economic Garden, Los Baños, Laguna, P. I.

PLATE 2

A prospective view of a tobacco field shaded with abacá cloth at the Los Baños Economic Garden, Los Baños, Laguna, P. I.

PLATE 3

Comparative graphs of weather records taken under shade of abacá cloth and under open condition (without shade).

PLATE 4.

Cross sections of shaded and not shaded tobacco leaves. Note frequency of stomata and of poor development of palisade cells of leaves shaded 4 weeks after transplanting.

PLATE 5

Comparative graphs of quality-value of Philippine shade-grown wrapper-leaf tobacco and imported Sumatra cigar-wrapper.

PLATE 1.

PLATE 2.

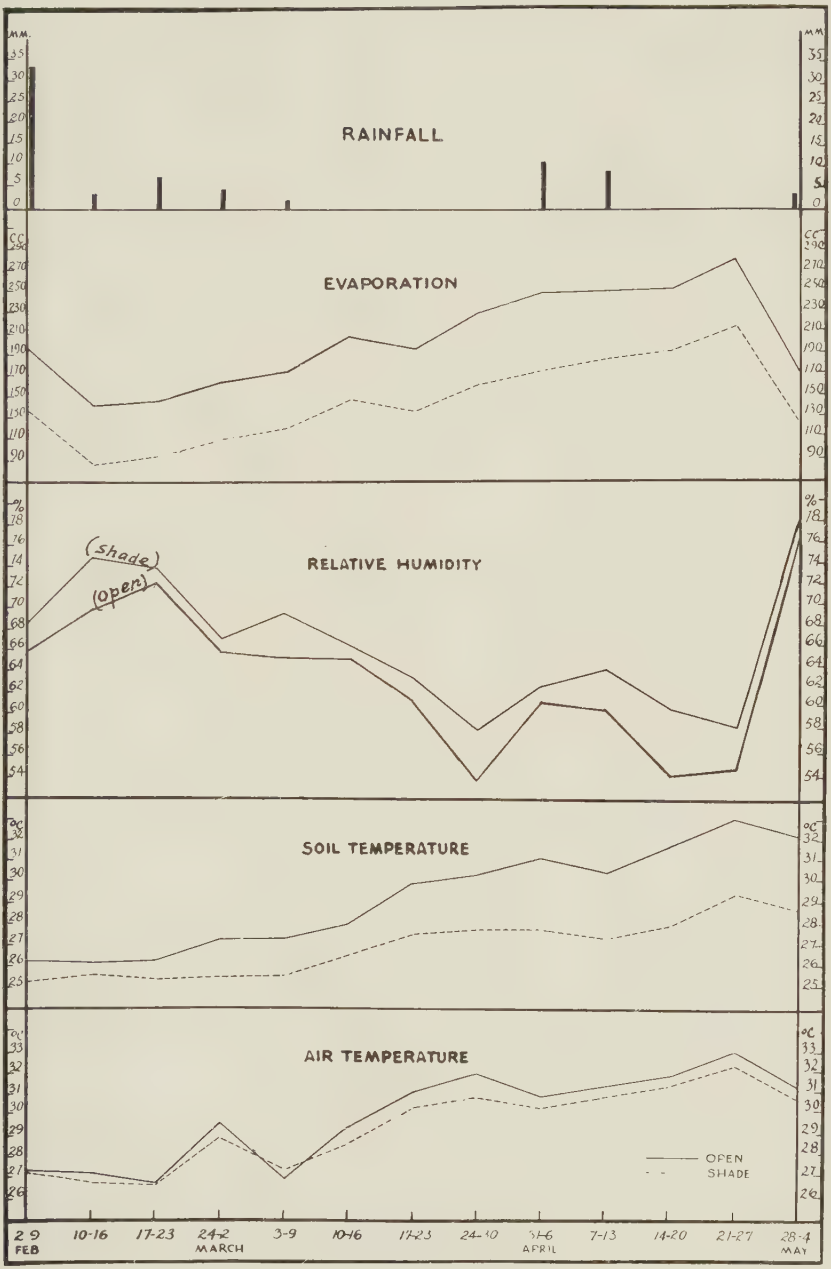
RAINFALL
EVAPORATION
RELATIVE HUMIDITY
(shade)
(open)
SOIL TEMPERATURE
AIR TEMPERATURE
OPEN
SHADE
29 FEB
10-16
17-23
24-2 MARCH
3-9
10-16
17-23
24-30
5-6 APRIL
7-13
14-20
21-27
28-4 MAY

PLATE 3.

EFFECT OF TIME OF SHADING UPON THE STRUCTURE OF TOBACCO LEAF

ILAGAN SUMATRA, NOT SHADED (OPEN GROWN)
I SUMATRA, SHADED 6 WEEKS AFTER TRANSPLANTING
I SUMATRA, SHADED 4 WEEKS AFTER TRANSPLANTING
SIMMABA, NOT SHADED (OPEN GROWN)
SIMMABA, SHADED 6 WEEKS AFTER TRANSPLANTING
SIMMABA SHADED 4 WEEKS AFTER TRANSPLANTING
VIZCAYA NOT SHADED (OPEN GROWN)
VIZCAYA SHADED 6 WEEKS AFTER TRANSPLANTING
VIZCAYA, SHADED 4 WEEKS AFTER TRANSPLANTING

PLATE 4.

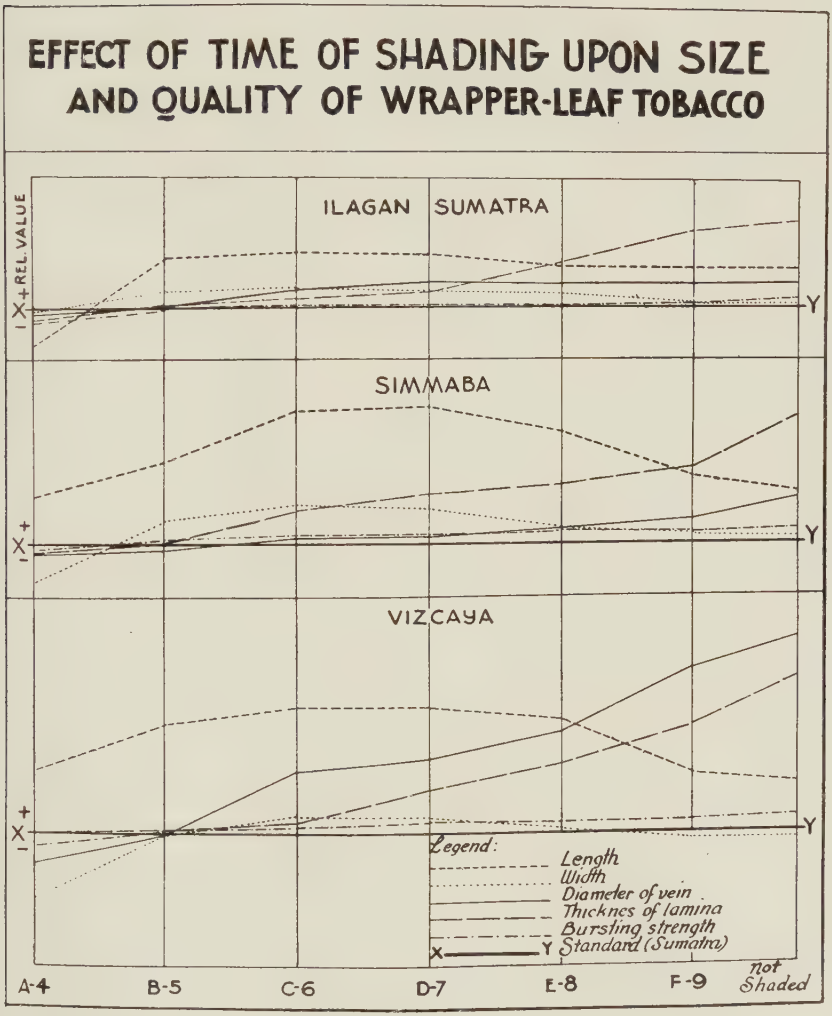
EFFECT OF TIME OF SHADING UPON SIZE AND QUALITY OF WRAPPER-LEAF TOBACCO
ILAGAN SUMATRA
SIMMABA
VIZCAYA
+REL VALUE
X
Y
Legend:
Length
Width
Diameter of vein
Thickness of lamina
Bursting strength
Standard (Sumatra)
A-4
B-5
C-6
D-7
E-8
F-9
not Shaded

PLATE 5.

THE ECONOMIC ASPECT OF GROWING BERMUDA ONION IN THE PHILIPPINES

By Aniano Elayda, Adriano M. Orgas, and Francisco de Jesus

Of the Bureau of Plant Industry

In any attempt to convince a farmer to grow a certain crop in his locality, there is only one thing that will induce him in deciding to undertake the task, and that is profit. This has been proved by the fact that crops that have been persistently grown are only those that have given profit to him. We may advise the farmer to grow a crop of high food value or one that has good export possibility. We may also advise him to improve, maintain, or restore soil fertility by cover-cropping, fertilizer application, or by the adoption of some soil-improvement schemes so that the land might not be depleted, but instead, made more fertile than it used to be. These are reasons why money and labor should be put into soil-fertility work, etc., but, unless the things recommended to accomplish these idealistic results pay, their wide adoption by the skeptical farmer will not follow. Under commercialized conditions of farming at present, probably few farmers will advocate the use of fertilizers in the planting of any crop unless they are sure that there is an affirmative answer to the question—Does it pay?

The object of this investigation was to determine the economic aspect of growing Bermuda onion in the Philippines. One of the principal requirements in growing this crop is an abundant supply of irrigation water. As this requirement is also a primary need in rice culture, the growing of Bermuda onion in rotation with early maturing rice in irrigated rice lands has been found very advisable. This scheme of rotation has been so highly satisfactory that it has taken very little effort in encouraging farmers to adopt it. In order to determine the income which could be realized from planting onion alone and in rotation with rice this study has been undertaken.

METHODS OF INVESTIGATION

The methods employed in carrying out this investigation were along the line of agricultural extension service by the Bureau

of Plant Industry to the farming public. The methods embrace four steps, as follows:

1. Determining the problem.
2. Finding the solution.
3. Demonstrating the solution of the problem under the farmer's conditions.
4. Having the practice adopted by the farmers.

The first three steps have been worked out successfully. The historical events leading to the development of Bermuda-onion growing industry began when Bermuda onion seeds were introduced from the Canary Islands in 1931 to 1933 and grown for trial purposes within two consecutive years. From 1933 to 1936 large scale plantings were undertaken in different parts of the country in coöperation with the farmers. The experimental and coöperative trials proved so highly successful that a final step calling for a carefully planned "sales campaign" was taken. As a result of the campaign which was carried out intensively and of the farmers' responses to grow this crop, the industry now has already taken a foothold, especially in the provinces of Nueva Ecija and Batangas.

The results of the investigation herein reported are based on records of farm operations by Bermuda-onion growers who actually undertook the work.

DISCUSSION OF RESULTS

1. *Field practices.*—The results of field practices in raising this crop are briefly described as follows:

(*a*) *Cultivation and watering by hand.*—This system of raising onions is applicable to small-scale production, especially in gardens. The labor involved is tedious and expensive for large-scale production.

(*b*) *Cultivation on land dependent upon rain or moisture in the soil.*—The land used for this system of raising onions is usually low-lying and inundated. As crop to be grown on land of such conditions undergoes considerable risk, because water inundating the place may be unusually high or rains may come late as to delay the planting time. At times drought may occur during the development of the crop. An onion crop dependent upon rains is considered uncertain of success.

(*c*) *Cultivation on mulched land with rice straw and with irrigation facilities.*—Under this system of raising onions, the land is either prepared by giving it adequate number of plowings and harrowings or just getting rid of weeds and rice stubbles by

cutting them close to the ground with bolos or big knives. Afterwards small ditches for irrigation and drainage purposes are dug close inside along the dikes. The land is then covered with straw to the thickness of about one inch when pressed. By mulching the field with straw the usual periodic loosening of the surface soil and weeding are eliminated.

(*d*) *Cultivation under clean culture with irrigation facilities.*—The condition of the land is similar to the one described in *c*, except that under this system the soil is put into a state of fine tilth before planting; and being mulched, the usual loosening of the soil and weeding are made.

The four systems of raising onions described above have been demonstrated by the Bureau of Plant Industry to the farmers under their own conditions. The systems described in *c* and *d* have been repeatedly demonstrated as practical and economical, so that they have found wide acceptance into the scheme of crop rotation with early maturing rice harvestable during the October and November periods.

(*e*) *Onion as a rotation crop after rice.*—The growing of onion in rotation with rice on land with irrigation facilities has already been successfully demonstrated in many provinces, particularly in Nueva Ecija and Batangas. The adoption of this scheme of rotation in the irrigated districts has already found wide acceptance among the rice planters in view of the adaptability of the onion plant when grown in irrigated rice lands having light soil. If the seedlings have the required vigor, the transplanting done about the month of December, and the plants given adequate irrigation water, crops produced therefrom will prove exceedingly profitable barring, of course, uncontrollable factors.

According to the report of the Rice Commission to the President of the Philippines (1936), the income of a landowner and a tenant per hectare of rice amounts to ₱31.87 and ₱37.50,[1] respectively. In order to throw more light on the economic aspect of growing onion after the harvest of rice on lands suitable for the former, the following computations are presented:

I. Under Muñoz, Nueva Ecija, conditions:

(1) ₱308.30 income of landowner from onion
₱ 31.87 income of landowner from rice

₱340.17 total income of landowner from rice and onion crops per hectare for one year.

[1] Based on 40 cavans per hectare, at ₱2.50 per cavan.

(2) ₱280.20 income of tenant from onion
₱ 37.50 income of tenant from rice

₱317.79 total income of tenant from rice and onion crops per hectare for one year.

II. Under Bongabon, Nueva Ecija, conditions:
(1) ₱390.90 income of landowner from onion
₱ 31.87 income of landowner from rice

₱422.77 total income of landowner from rice and onion crops per hectare for one year.
(2) ₱321.98 income of tenant from onion
₱ 37.50 income of tenant from rice

₱359.48 total income of tenant from rice and onion crops per hectare for one year.

III. Under Lemery, Batangas, conditions:
(1) ₱653.31 income of landowner from onion
₱ 31.87 income of landowner from rice

₱685.18 total income of landowner from rice and onion crops per hectare for one year.
(2) ₱480.50 income of tenant from onion
₱ 37.50 income of tenant from rice

₱518.00 total income of tenant from rice and onion crops per hectare for one year.

As reported by the Rice Commission, the average land holding of a tenant (kasamá) is about 2.5 hectares, producing an average total of 100 cavans of palay per year. Deducting from this total about 20 cavans for seed, planting, harvesting, threshing, and other expenses, there would remain 80 cavans to be divided between the landowner and the tenant, thus giving the tenant for his work and that of his family and for his investments in animals and implements a yearly income of only 40 cavans of palay. Oftentimes this share in the crop goes to the landowner rather than to the tenant, because during the year the tenant borrows money or rice from the landowner to provide himself and members of his family with food and other necessities. If palay sells at ₱1.75 per cavan, the tenant or small farmer would receive ₱70 for his total crop or a daily wage for the tenant and his family of only ₱0.19; and if a cavan sells at ₱3 the tenant or small farmer would receive ₱120 for himself and his family or a daily wage of only ₱0.33. Usually a tenant or a small farmer has no opportunity to find any other opening for

gainful employment and a daily wage of ₱0.19 to 0.33 for him and his family would be too meager to maintain a decent standard of living. On the basis of ₱280.29, ₱331.98 and ₱480.50 net income per hectare from onions for a period of 6 months, the daily wages for him and his family would be ₱1.52, ₱1.80, and ₱2.62, respectively. Hence, even if the farmer raises onions alone, his income would tide him over comfortably for the year and would in turn surprisingly increase his purchasing power and improve his living standard beyond his expectation.

2. *Cost of production.*—Investigations on the production cost of raising onions under the conditions described in systems (*c*) and (*d*) were undertaken and data on the results thereof are herein presented.

The cost of production as far as it could be ascertained from the data and information from representative growers in Nueva Ecija and Batangas where the growing of this crop has been well established are as follows:

TABLE I.—*Cost of production on 9.25 hectares of Bermuda onion at Bagongsikat, Muñoz, Nueva Ecija, 1935–1936 crop.*

Items of operation.	Man	Animal	Cost
	Day	*Day*	
1. Seeds, 71 kilos at ₱8.00			₱568.00
2. Seed-bed preparation, area—2,769 sq. m.:			
a. Plowing and harrowing (4 times)	8	8	8.00
b. Forming beds, etc.	35		14.00
c. Sowing of seeds, mulching with rice straw, watering, etc.	35		14.00
3. Care of nursery beds (weeding, watering, fertilizing, etc.) for 60 days	1,278		511.20
4. 213 kilos of fertilizer			23.43
5. Preparation of field (cutting grass and rice stubbles), weeding, and mulching to the thickness, of 1 inch when pressed; digging canals close inside along dikes of each paddy	925		370.00
6. Transplanting, lifting of seedlings, etc.	1,480		572.00
7. Irrigation, 7 times (2 during December, 2 during January, and 3 during February)	28		11.20
8. Harvesting:			
a. Pulling, drying, cutting, etc.	462		184.80
b. Transporting, from field to shed	45		45.00
9. Drying, curing, sacking, etc.	137		54.80
10. Cost of 2,775 sacks at containers at ₱0.08			222.00
Total expenses			₱2,618.43
Average expenses per hectare			₱283.07

No charge is accounted for administration or labor of landowner. This project was under the administration of an ex-

perienced planter who planted onion on the lowland-rice-paddy land mulched with rice straw. The soil is rather light loamy clay. There is abundant cheap and readily available irrigation water supply. The quantity of seeds used was two-thirds more than the requirement for the 9.25 hectares due to the destruction of the seedlings by the repeated typhoons and heavy rains occurring at the time. One hectare on the average required only 3 kilos of seeds. The onion crop was planted after the rice crop was harvested during the October and November periods. The mulched system of culture eliminated plowing, cultivation, and weeding which are among the heaviest items in the cost of producing the crop.

TABLE II.—*Cost of production of one hectare of Bermuda onion at Calaanan, Bongabon, Nueva Ecija, 1935–1936 crop.*

Items of operation.	Man	Animal	Cost
	Day	*Day*	
1. Seeds, 4.33 kilos at ₱8			₱34.64
2. Seed-bed preparation, area 160 sq. m.:			
a. Plowing and harrowing (3 times)	2	2	2.00
b. Forming beds, etc.	8		2.40
c. Sowing of seeds, watering, etc.	4		1.20
3. Care of seed beds for 60 days:			
a. Weeding and watering, etc.	40		12.00
4. Preparation of the field:			
a. First plowing	10	10	10.00
b. First harrowing, etc.	6	6	6.00
c. Second plowing	8	8	8.00
d. Second harrowing	4	4	4.00
e. Third plowing	5	5	5.00
f. Third harrowing	4	4	4.00
g. Forming beds	100	1	31.00
5. Transplanting, including lifting of seedlings, distributing, watering, etc.	166		49.80
6. Irrigating (8 times)	24		7.20
7. Weeding and cultivation (4 times)	120		36.00
8. Harvesting and transportation to shed	20	2	7.40
9. Drying, cutting of leaves, curing, sacking, etc.	83		24.90
10. 300 gunny sacks			30.00
Total expenses			₱275.54

No charge is accounted for administration. This project was under the administration of an experienced planter. The system of planting was clean-culture, employing the usual cultivation and weeding of the land. The land is an ordinary lowland-rice-paddy with abundant irrigation water. The soil is sandy loam with good natural drainage. Cultivation and weeding were done exclusively by hand.

TABLE III.—*Cost of production of one hectare of Bermuda onion at Sinisian, Lemery, Batangas, 1933–1934 crop.*

Items of operation.	Man	Animal	Cost
	Day	*Day*	
1. Seeds, 2.5 kilos at ₱8.00			₱20.00
2. Seed-bed preparation and sowing, 200 sq. m.	87		43.50
3. Care of seedlings (weeding and watering, etc.) for 56 days	15		7.50
4. Preparation of field for planting:			
a. First plowing	15	15	12.00
b. First harrowing, including clearing of land	30	30	24.00
c. Second plowing	15	15	12.00
d. Second harrowing	15	15	12.00
e. Third plowing	15	15	12.00
f. Third harrowing	15	15	12.00
g. Forming beds	75		37.50
5. Transplanting, including lifting of seedlings, distribution of same, watering, etc.	180		90.00
6. Irrigation (6 times)	42		21.00
7. Cultivation and weeding (3 times)	75		37.50
8. Harvesting, hauling, cutting of leaves, drying, curing, etc.	180		90.00
9. 472 sacks			33.04
10. Sacking	15		7.50
Total expenses			₱471.54

No charge for administration and labor of landowner is accounted. This project was under the administration of an experienced Bermuda-onion planter in Lemery, Batangas, where the "small-bulbed-type" onions (sibuyas Tagalog) had been grown for a number of years. The expenses incurred in some of the items are quite high. In the preparation of seedbeds a big amount was spent as the land was infested with persistent weeds. The thoroughness of the preparation of the seedbeds was manifested by the very low amount spent in their care. The first harrowing was also expensive as the roots of weeds had to be gathered thoroughly. Transplanting, including pulling of seedlings and distributing them in the field among the planters and watering the newly transplanted plants by the bucket system, was laborious, hence, quite expensive. A big amount was likewise spent in hauling, cutting of leaves, drying in the sun, etc., because the process of drying onions under the sun and curing them without the use of curing sheds, and separating rotten from good onions necessitated plenty of labor.

As may be seen in Table I, the total expenses for running an onion farm of 9.25 hectares is ₱2,618.43 or ₱283.07 per hectare. Were it not for the rather heavy loss of seeds that increased the cash expenses of both the landowner and tenant, the total

expenses would have been lower. The items of operation, such as plowing, cultivation, and weeding are heavy items in the cost of producing onions and these were eliminated by the use of mulched system of culture. If these were cash expenses their elimination would have been a great saving on the part of the tenant. The cost of 2,775 gunny sacks was shouldered by the landowner and it seems that this arrangement was fair enough because all the labor operations were practically accomplished by the tenant. The expenses for transplanting were ₱592, the biggest cash expenses, and this amount is more than twice that paid by the landowner for sacks. Cash advances were given to the tenant for transplanting expenses.

By eliminating the items of cultivation and weeding by the use of the mulched system of growing onions as they appear in Tables II and III, the tenants had reduced their expenses, respectively, by ₱333 and ₱346.87. Similarly, the method used in the preparation of the field for transplanting afforded the tenant considerable savings. If the preparation of the fields as it appears in Tables II and III was the one used in the mulched system of culture shown in Table I, the costs incidental thereto would have been ₱629 or ₱1,123.87, instead of ₱370—thereby resulting in a saving of ₱259 or ₱753.87.

In Tables I, II and III, the same methods of computation were used with the only difference that in Table I plowing of the field, cultivation, and weeding are not included. In all cases, since the services of the animals and implements have been evaluated and paid for, depreciation is already accounted. There are no charges for administration.

The expenses incident to the control of pests and diseases are not included because the crops in Nueva Ecija and Batangas where this study was made were practically freed from diseases and pests. However, there had been observed in the past more or less serious damage on the crop caused by onion thrips. In anticipation, therefore, that a crop might be menaced by a malady, it is always safe to provide for disease-control expenses.

3. *Marketing.*—While this product is not yet considered a major crop for the present, it is gratifying to note that there are quite a number of farmers scattered in several provinces who are experienced onion growers and there are many more who are getting interested in its culture due, among other things. to its being a crop of high cash value as compared with others. One of the difficulties in exploiting a crop not usually cultivated

in a country is that of finding an established market. This, however, does not concern onions, for there has already been a long-established market for it in the Philippines. The Philippine trade from 1931 to 1934 dealt with an average of 14,394,896.5 kilograms of imported onions valued at ₱516,081.50.

In marketing Bermuda onions in the Philippines, there are a few more or less fixed conditions to consider in order to render the raising of this product on a commercial scale less hazardous, as follows:

1. Properly matured and cured crop.
2. Properly cleaned and graded crop.
3. Properly packed crop in attractive containers of standard size.
4. Sufficient buyers contracted before harvesting.

Attention to the first consideration will insure good quality in the onion itself, besides making it a better keeper and shipper. With the four points mentioned closely observed, the grower may confidently expect the best price that the market will command during any given year and under all conditions. Poor stuff may result in a profit for the grower during a season of price level, but it never may sell as the high-class stock at any time. When a grower produces onions that have good quality, he is certain of the best price the market can afford, be that f. o. b. sales, selling en route, or on consignment. As most onion importers or wholesale dealers give preference to foreign-grown onions, it is safe for the local growers to locate buyers before the harvest of the crop to obviate the risk of not being able to sell the crop at a good profit.

4. *Income of the landowner and tenant.*—Under the prevailing conditions of tenancy in the production of this crop, the tenant pays for one-half the cost of seeds and performs all the labor required in the raising of Bermuda onions, while the landowner supplies the land and irrigation facilities, pays one-half of the cost of seeds and the whole cost of sacks required in the marketing of the crop. The product is equally divided between the landowner and the tenant.

(*a*) *Income of the landowner.*—In Table I the income and share of the landowner in sacks of onions (one sack weighs 40 kilos) are as follows:

At 2,775 sacks of onions from 9.25 Has. and divided by 2	sacks	1,387.5
At ₱2.50 per sack of onion, gross income will be 1,387.5 × ₱2.50		₱3,468.75

His cash expenses are as follows:

One-half of seeds (½ × 71 kilos) at ₱8 per kilo	₱284.00
Cost of sacks	222.00
Total	₱506.00

Deducting the expenses from the gross income, the result is as follows:

Income (gross)	₱3,468.75
Expenses	506.00
Interest and administration	₱2,962.75

The above income of the landowner from 9.25 hectares represents the interest on the cash investment and on land and the administration income. There are no actual data or information about the price of the land and the taxes paid. However, taking ₱2.63 as the average tax paid per hectare of rice land and around ₱300 [2] as the average price of same, and the interest on investment at 6 per cent per year, the total administration expenses of the landowner for the 9.25 hectares are as follows:

Seeds	₱284.00
Land tax (for ½ year)	12.17
Sacks	222.00
Total	₱518.17

Interest on investment at 6 per cent for ½ year:

Land—₱300 × 9.25 equals ₱2,775 divided by 2 multiplied by 6 % or for ½ year	₱83.25
Cash expenses—₱518.17 × 6 % equals ₱31.09 divided by 2 or for ½ year	15.55
Total	₱98.80

Total expenses:

Interest on investments	₱98.80
Cash expenses	518.17
Total cash expenses	₱616.97

The administration income of the landowner for 9.25 hectares is as follows:

Gross income	₱3,468.75
Total expenses	616.97
Administration income	₱2,851.78
Administration income per hectare	₱308.30

[2] Report of the Rice Commission.

The above income represents the net profit on the investment plus the cost of supervision made by the landowner. Taking the average price of rice land to be around ₱300 per hectare, the total investment on the 9.25 hectares would be ₱2,775; and adding to this the cash investment for seeds and sacks amounting to ₱506, gives a total investment of ₱3,281. Basing on ₱2,962.75 (interest and administration) and ₱3,281 (total investment), the rate of income would be ₱2,962.75 divided by ₱3,281 or 90.3 per cent of the total investment for a period of 6 months as against the maximum legal interest of 6 per cent if cash money were deposited in a bank.

(*b*) *Income of the tenant.*—On the same sharing basis as the landowner, the gross income of the tenant is ₱3,468.75. The items which require his expenses are as follows:

One-half of seeds	₱284.00
Transplanting	592.00
Total cash expenses	₱876.00

So, the labor income of the tenant from 9.25 hectares is ₱3,468.75 minus ₱376 equals ₱2,592.75 or ₱280.29 per hectare.

In Tables II and III, the landowners obtained a total share of the harvest in sacks of onions (one sack weighs 40 kilos) respectively, as follows:

At 300 sacks yields 300/2	150 sacks
At 472 sacks yields 472/2	236 sacks

The gross incomes are as follows:

At ₱3 per sack (3 × ₱150)	₱450.00
At ₱3 per sack (3 × ₱236)	708.00

The landowners' cash expenses are as follows:

	Table II	*Table III*
One-half of seeds	₱17.32	₱10.00
Empty sacks	30.00	33.04
Total expenses	₱47.32	₱43.04

Deducting the expenses from the gross income, the results are as follows:

	Table II	*Table III*
Income	₱450.00	₱708.00
Expenses	47.32	43.04
Interest and administration	₱402.68	₱664.96

The income from one hectare each of onion projects corresponding to ₱402.68 and ₱664.96, respectively, represents the

interests on the cash investments and on land and the administration income of the landowners.

Considering taxes, price of land, and interest on investment at 6 per cent rate per year, the total expenses and administration income per hectare of the landowners for a period of 6 months for each hectare project are as follows:

Cash expenses:

	Table II	*Table III*
Seeds	₱17.32	₱10.00
Sacks	30.00	33.04
Land taxes for ½ year	1.32	1.32
Total expenses	₱48.64	₱44.36

Interest on investment at 6% for ½ year:

Land, ₱300 × 6%, divided by 2	₱9.00	₱9.00
Cash expenses—administration income of landowners (₱48.64 and ₱44.36 × 6%) divided by 2	1.46	1.33
Total	₱10.46	₱10.33
Total expenses for each hectare project	₱59.10	₱54.69

The administration incomes are as follows:

Gross income	₱450.00	₱708.00
Total expenses	59.10	54.69
Administration income	₱390.90	₱653.31

The above incomes represent the net profit on the investment plus the cost of supervision on the part of the landowners.

Under Bongabon, Nueva Ecija, conditions, if the total investment is ₱347.32 which includes land, sacks, and seeds, and ₱390.90 is the income, the interest rate for 6 months would be 112.5 per cent; and under Lemery, Batangas, conditions, the interest rate would be 190.4 per cent for 6 months basing on ₱343.04 investment which includes prices of land, seeds, and sacks and an income of ₱653.31.

The income of the tenant from each hectare-project is as follows:

At 300 sacks yields 300/2	150 sacks of onions
At 472 sacks yields 472/2	236 sacks of onions

At ₱3 per sack of onions, the gross incomes are as follows:

At 300 sacks	300/2 × ₱3 or ₱450.00
At 472 sacks	472/2 × ₱3 or 708.00

Their cash expenses are as follows:

	Table II	*Table III*
One-half of seeds	₱17.32	₱10.00
Transplanting	49.80	90.00
Cultivation and weeding	36.00	37.00
Preparation for market	24.90	90.00
Total expenses	₱128.02	₱227.00

Thus the labor incomes of the tenants are as follows: In Table II, ₱450 minus ₱128.02 equals ₱321.98, labor income; and in Table III, ₱708 minus ₱227 equals ₱480, labor income.

SUMMARY AND CONCLUSIONS

1. This paper presents the results of an investigation on the cost of production and income of growing Bermuda onions in Nueva Ecija and Batangas Provinces.

2. There is an established market for onions in the Philippines as this commodity is being used daily for culinary purposes in every home. The Philippine trade from 1931 to 1934 dealt with an average of 14,394,896.5 kilos of imported onions, valued at ₱516,081.50.

3. The practical methods of growing onions on a commercial scale are by the mulched and clean cultures—the former eliminates cultivation and weeding and the land may either be tilled or untilled; and the latter includes cultivation, weeding, and thorough preparation of the land for transplanting. Irrigation is indispensable to both cultures.

4. Under Muñoz, Nueva Ecija, conditions, the total expenses, including cash and evaluated costs for the different items of operation, are ₱2,618.43 for 9.25 hectares or ₱283.07 per hectare. The cash expenses of the landowner are ₱518.17 or ₱616.97 (including taxes and interest on the cash investment on the value of the land); and the cash expenses of the tenant are ₱876. The income of the landowner is ₱2,962.75 or ₱2,851.78 (excluding taxes and interest on the value of the land and cash investments) or a net income of ₱308.30 per hectare; and the income of the tenant is ₱2,592.75 or ₱280.29 per hectare. The rate of interest on the total investment is 90.3 per cent for a period of six months.

5. Under Bonga̍bon, Nueva Ecija, conditions, the total expenses for one hectare-onion project is ₱276.44, including cash expenses and evaluated items of operation. The cash expenses

of the landowner is ₱47.32 and the net income is ₱664.96 and, considering taxes and interest on investment, the administration income is ₱390.90. If ₱347.32 is taken as the investments on land value, sacks, and seeds, the income rate or interest rate for 6 months would be 112.5 per cent.

6. Under Lemery, Batangas, conditions, the total expenses for one hectare-onion project are ₱471.54, including cash expenses and evaluated items of operation. The cash expenses are ₱43.04 for seeds and sacks or ₱54.69, including taxes and interest on investment. Basing on these figures, the net income is ₱664.96 or ₱653.31. Investments include value of the land, sacks, seeds and interest on investment amounting to ₱343.04 and on the basis of ₱653.31 administration income the rate of interest on the investment is 190.4 per cent for 6 months.

7. The income of the tenant from the 9.25-hectare-onion project under Muñoz conditions is ₱2,592.75 or ₱280.29 per hectare; ₱321.98 for one hectare-onion project under Bonga̍bon conditions and ₱480.50 under Lemery conditions.

8. The combined incomes of the landowner from rice and onion projects per hectare for 1 year are ₱340.17, ₱422.77, and ₱685.18, respectively, and the combined incomes of the tenant are ₱317.79, ₱359.48, and ₱518, respectively.

9. From 2.5 hectares of rice, average holding of a tenant, he would receive only ₱0.19 to ₱0.33 daily wages for himself and his family for one year's farm work as compared with a daily wage of ₱1.52 to ₱2.62 for practically 6 months work for onion.

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CROP FERNS

By Edwin Bingham Copeland and Tomas G. Collado

Very many ferns are edible. As primitive man knew his resources, we must suppose that very many ferns entered into his diet. As man not too far from primitive is still widespread, many ferns must still be eaten. As a matter of record, many ferns are eaten. The largest list of those eaten seems to be that in Heyne's Nuttige Plaanten van Java, but there are many scattered references to such cases. The younger Hooker listed those known to him in his *Himalayan Journal.* At least three species have been named in appreciation of their food value: *Asplenium esculentum* Burm, *Pteris esculenta* Forster, and *Ellebocarpus esculentus* Kaulfuss.

Considering the prominent place of ferns in the native vegetation of warm and moist countries, the failure of any of them to come into cultivation is a notable phenomenon. If one considers that *pacó, Athyrium esculentum* (just referred to by its first name, *Asplenium*) comes into the markets throughout the great Malay region, always collected wild, its failure anywhere to be brought into culture is the more remarkable. There may be wild plants, as for example, the rattans which are impracticable to cultivate; but it is uniform history that no plant in its wild state can compete with the same plant in culture once there is any real demand for it.

With this fact in mind, we had no more than begun the establishment of the Economic Garden, when we started to study the practicability of bringing *pacó* into culture. It is common along creeks on wet ground, usually in the brush. From such places we secured enough plants for a small plot, and began to observe their behavior, particularly the rate of production of fronds and their rate of growth. Like very nearly all ferns, *pacó* is perennial. In those first cultures, during some two months, we noticed no intimation that there might be a method of reproduction more rapid than by spores, and the growth of plants of various sizes was not rapid enough to suggest maturity, that is, a size and vigor sufficient for a steady harvest in less than two or three years from germination. The effort

apparently necessary to bring a plot into production, otherwise than by transplanting from their native habitat plants already well grown, made this fern a most unpromising crop plant; its development as a crop dependent upon a wild source of plants was clearly not worth considering. A month or so later, we found that *pacó* multiplied rapidly by runners; but by this time our attention was focussed on *Ceratopteris*, where it remained for eighteen months.

Ceratopteris siliquosa presented itself to us. The first plant appeared spontaneously in the nursery late in June, 1932. Others appeared in the same manner a little later, but this first individual was the source of all our cultures for more than a year. I considered it as a rarity among ferns, both as an annual, and as reputed to be aquatic. It was eaten in the Cagayan valley, and came constantly into the markets during the rainy season, selling at an established price of five fronds for one centavo. Here was an edible fern which, instead of requiring two or three years from the spore to maturity, evidently needed only a few months. We accordingly gave it all the attention available for any fern culture.

Spores were mature a few weeks after its discovery. We sowed these on wet soil, and within two months were able to pick out two hundred plants, set 20 by 20 cm., and formed our first two beds. This transplanting of sporelings, from mud into mud, is ideally easy, and the resulting stand should be perfect. Obviously, since there is a massive production of spores, any desired number of plants can be produced in this manner. However, since this first planting of a plot we have used sporelings only twice, once to compare them with vegetatively produced plants and once to test their susceptibility to disease.

Before the first bed was three months old, we observed the production of buds on old leaves which, with age, bent or fell backward onto the mud. As these buds provided ample material for our wants at that time, we ceased to depend upon reproduction by spores.

We may digress at this point to note, as an illustration of failure to use published information, that we let ourselves learn locally that this plant is edible, and that it can be reproduced by buds, although both facts have been published conclusively. As to its edibility, a much repeated couple of lines says that the young leaves can be eaten (Hooker, Engler and Prantl, Bower, et al.) with added touches by way of variety, to the effect that

this is done in the East Indies, and by the poor. All of these statements seem to be traceable back to Rumphius' *Flora Amboinensis 6* (1750) 176, Pl. 74, f. 1. He reports this use by the Buginese and Macassarese, but explicitly not by the Amboinese. It appears from Heyne's *Nuttige Plaanten* that it is not eaten in Java, Heyne citing Ridley and Rumphius as authorities for its use elsewhere. It is not mentioned in Watt's Dictionary of Industrial Products of India, where a number of other ferns are listed as eaten. Its use is evidently not at all widespread. In the Philippines, although it occurs in proper places everywhere, it seems to be eaten only at the north end of Luzon.

Constituting a family (*Parkeriaceae*) by itself, *Ceratopteris* has received much attention from botanists. Its morphology is known in detail, but hardly concerns us in a paper primarily of economic interest. The common view has been not only that the genus is a family, but that it has only one species. Judging by herbarium specimens, and by the account of Benedict, Bull. Torrey Bot. Club *36* (1909) 463, the American *C. pteridoides* (Hooker) Hieron. is easily specifically distinct from our species; it ranges from Brazil to Florida. Benedict recognizes three other American species of more limited distribution. *C. cornuta* Le Pr. has been described from Africa. The known range of *C. siliquosa* is from Malaya to Madagascar, the Himalayas, Japan, and Queensland. It is presumable that all species are edible. In fact, as *C. pteridoides* appears to be more succulent than *C. siliquosa,* it may be even superior as a salad.

Our plant is not really aquatic. It starts on wet ground. Even after the first leaves are developed in the air, it can grow up through very shallow water only. The mature plant endures constant shallow submersion of its base, but seems to live longer and be equally thrifty if the ground is merely kept thoroughly wet at all times. We have never seen a floating plant. *C. pteridoides* is described as commonly floating, eventually rooting in the mud at the margin of the water; and my herbarium specimens of it all appear to have been floating plants. Benedict regards this as a diagnostic difference between the two species, and so far as our plant is concerned, he would seem to be right. It must not be overlooked, however, that Rumphius described his *Millifolium aquaticum* as behaving exactly as the American plant has since been found to do. It may be that we have more than one species in the Orient.

We turn now to the culture of *Ceratopteris*.

The "seed-bed," if spores are used, has merely to be wet, bare ground, and should be in partial shade. The first sporelings are large enough to be transplanted after about two months. They can be transplanted when 5 cm. tall, or even smaller; but the total attention required is less if they are allowed to become 10 cm. tall before transplanting. Unless the seed-bed is too crowded to permit the moving of enough mud to prevent much damage to the roots, no leaves need to be removed, no particular care is needed after transplanting, and no plants should require replacement.

If buds are used, the seed-bed should be worked and watered to the consistency of thick soup, and should be perfectly flat. As planting material, mature but not old leaves are used and pressed, on their backs, into the mud, so shallow that the rachis is only partly submerged. In making a seed-bed, the leaves are placed as close together as will let each young plant have room to develop.

In our cultures, all descended from a single plant, and probably uncontaminated in the sexual stage, and since *Ceratopteris* was a scarce plant in our nursery, differences in the freedom of bud production were observed in the first generation. Buds were potentially present in all axils of the axes of the frond. In the fronds of most plants they remain potential, commonly just visible along the main rachis, or not even there, as long as the frond maintains its position in the air; finally the frond dies, or else falls backward onto the mud, and in the latter case the buds are likely to become active. Occasional single plants behave differently in that buds on their fronds develop with considerable freedom, even as early as the production of the first spores. If these plants are used as vegetative parents, the offspring behave in the same manner. Leaves for food are harvested before such a trait could affect them directly. Still, because these spontaneously freely budding plants are weakened thereby, we have avoided them as parent plants.

We believe that it is worth while to be careful to transplant material very uniform in size. Exercising this care, we transplanted at one time hardly more than one hundred plants from each square meter of seed-bed. The same seed-bed could provide material as often as twice a week for a considerable time. It is probably not expedient to use a seed-bed until it is completely exhausted; however, we have no sound evidence that the young plants backward in early development are per-

manently weak. Plants from spores are fit to be transplanted rather smaller than those from buds; but, in our limited experience, the spore-planted bed was more crowded, with the result that it yielded hardly more plants of very uniform size than the budding bed.

The gain in time by using buds is fully two months. From spore-sowing to transplanting, this period is about one hundred days; from the bedding-down of fronds, about one month.

In transplanting, we spaced our plants at first 20 by 20 cm., then 20 by 30 cm., 30 by 30 cm., 30 by 50 cm., and 40 by 50 cm. Under good conditions, 30 by 30 cm. is probably preferable to any other spacing. For convenience in care and in harvesting, we planted in beds of four rows, the space between beds being 50 cm. The gross width of each bed is thus 140 cm. This spacing will provide about 95,000 plants per hectare.

After transplanting, the chief care is to see that the place is constantly wet. The plants can endure a considerable degree of temporary dryness. Small plants, once well-established, live and produce spores in flower-pots in the nursery, and even on the nursery soil, with only as much moisture as most other plants require. But, for the production of a crop, such plants are altogether valueless. The young fronds grow too slowly and remain too small. We suspect that constantly very wet ground is preferable to shallow water, if no pests are present, but this has not been proven. If it is true, it is because the stems of plants in water grow upward more rapidly, and length of stem seems to be a tendency to short life.

Saturated soil is the habitat of many weeds. Low-growing weeds are perhaps harmless, but those that can reach a height of 30 cm. or more should be pulled, and smothered in the mud. The fern itself grows so lustily that weeding is no great task.

Harvesting consists in the collection of the very young, wholly tender, and fiberless fronds. These are cut about a centimeter above the base of the stipe (leaf-stem). Our practice at first was to harvest nearly a week after rapid growth began, when the height was 20 to 25 cm. At this time the texture is that of ordinary canned asparagus, the base too fibrous to be cut with a fork.

As we were introducing a new product, it seemed expedient to expose it to no possible criticism; so we advanced the harvest two or three days, cutting the leaves about 12 cm. long. An equally long tender tip could be harvested later, but the prompter harvest prevents the use of any of the plant's strength in pro-

ducing a structure to be wasted. We left a centimeter at the base, to reduce the chance that decay would reach from the cut surface; whether or not this precaution is necessary, we do not know.

The young fronds harvested from strong plants were a centimeter or more in diameter at the base, and somewhat smaller at the top; that is, they were not quite as thick as asparagus, but the difference was not great. Our sales in Manila have been by the kilogram at a price, for produce of the size just described, about equivalent to the local one of five fronds for a centavo.

There are open questions as to the technique of harvest. For home use, fronds could be harvested six weeks after transplanting, but these are not of proper size for the market. It is better to postpone any harvesting until the plants reach their maximum strength with, say, four fronds at least 40 cm. tall in the dry season and at least 50 cm. tall during the rains. Fronds sometimes reach a length of 80 cm.

It being agreed that a plant should reach its maximum vigor before harvest begins, we have experimented inconclusively as to the rate of harvest. This depends obviously upon the number of active expanded fronds necessary to produce very vigorous new ones for harvest, upon the period during which expanded fronds remain sufficiently active to accomplish this result, and upon the longevity of the plant. In preliminary experiments, designed primarily to determine the possibility of keeping plants vigorous during the dry season, we kept individual plants alive for a full year. It appears now that it is impracticable to count on such long life. In practice, no bed has endured active harvest for much more than two months. We have tested the harvest of one frond in every three produced of alternate fronds, and of two out of three. The results are inconclusive, partly because other factors have interfered with the vigor of some beds and partly to the abrupt termination of our study. It is obvious that it must at some time become advisable to harvest all young fronds as long as some are produced. We would have approximately doubted our harvest if we had adopted this procedure a month before a fungus epidemic wiped our cultures out. And it may be that it would be wise always to do this, from the moment the harvest begins.

Reporting the field culture only, and ignoring production in preliminary trials, we harvested, from October 16 to January 12, 38,106 fronds from plots containing 11,026 plants. Some

of these plots had yielded most of their crop before this count began; some yielded poorly because they were experimented with in various ways; and the whole culture was abruptly stopped before others had ceased to yield. One block of about 2,000 plants yielded an average of about six fronds in four weeks, and should have yielded several more afterward. Reckoning very conservatively, there is no question that a yield of five fronds per plant is obtainable; we believe that, harvesting alternate fronds, or two out of three, a yield of eight may be expected with confidence. One bed of 208 plants yielded 50 fronds a day for three weeks (of seven days) of dependable record. The fifty continued to come in regularly for another three weeks, but it developed then that the zealous harvester was making up the count from adjacent beds when necessary.

Valuing five fronds at one centavo, an average yield of five yields ₱950 a hectare. The corresponding cost is about ₱400; this is mostly the cost of harvesting. As we used old rice paddies, the preparation of the land was cheap. Transplanting costs as much as with rice, though there were not half as many plants, because we used higher priced and less expert labor. As with rice, the fern occupies the land for half of the year. The difference in income will be evident to every rice grower.

We began this work with the idea that we were producing a new kind of greens, to be eaten like spinach. When it appeared that we could produce it at a price to compete with spinach, we instigated a study of the practicability of canning it. It can be canned, but the first tests produced too mushy a substance, and brownish in color. By this time we had found that we had a very fine salad green, and our most discriminating Manila consumers made the same discovery. The Army and Navy Club, for example, put it on the menu as Philippine asparagus. We have not tested the possibility of canning it as asparagus, but it may be difficult, because it has less body. As greens or salad, its reception has proven that it is much better than palatable. Beside satisfying a good and growing local demand, we were shipping ten to twenty kilos a day to Manila in December, 1933. The order jumped to fifty kilos, the exact day that the fungus epidemic kept us from harvesting a good crop.

We have found no record of any insect or fungus enemy of *Ceratopteris*, and it may be that in nature it effectively has none. But solid stands of any plant are very exceptional in the humid tropics. Far more than in temperature lands, it is

tropical experience that any extensive and solid planting will presently be ravaged by pest and disease. The first pest observed on our fern was an undetermined microlepidopteron which breeds on the fronds of various other ferns, nesting by tying the segments of the frond-tips together, forming a ball, within which the larva grows, eating the young segments of the host. The nests are conspicuous, and are removed and destroyed by hand. The damage was not serious, and is unlikely to become so.

At the height of the harvest, another microlepidopteron appeared. Its larva traveled up through the growing stipe, leaving a channel hardly visible at the bottom, a millimeter in diameter at a height of ten or fifteen centimeters. When our harvest ended, nearly ten per cent of the young fronds were infested, sometimes with several larvae in a single stipe. The egg was presumably laid before rapid elongation of the stipe began; even so, it must hatch very quickly. The larva must advance at a rate of several centimeters a day, and grow with corresponding speed. In infected harvested fronds, it was usually within five centimeters of the tip. Its damage was obviously serious and the degree of infestation was increasing rapidly. As there was no external evidence of its presence up to the stage at which we harvested the fronds, there was no possibility of direct attack on it. The fronds permitted to develop, while we harvested a part of those produced, were of course infected in the same proportion, and insured the multiplication of the pest. In its presence, it is obvious that every frond should be harvested. As the point of infection is usually very near the base (it is probably at any exposed point on the embryonic frond) infection can probably be prevented by submersion. We set up an experiment to determine the necessary depth of water; but before it yielded any result, every plant in it was killed by a fungus.

As to this fungus, the one thing we really know is that it killed most of the plants in our cultures, and that not one plant in more than thirty thousand resisted it sufficiently to retain any value. Some plants did remain alive for months, producing only weak leaves. Young plants and old ones succumbed together.

We had been aware of trouble in one plot for a month. Beginning in one corner, death advanced across the bed at a rate of about two meters a week. Sclerotia were present, and as

Sclerotium Rolfsii was everywhere locally, we supposed it to be the lethal agent. It happened to be a busy time, and we were not alarmed; we have controlled this fungus on various hosts. An occasional plant elsewhere died, apparently from the same cause, without making us worry. And then, so suddenly that we hardly saw it happen, our entire culture was wiped out.

Our original nursery, 500 meters away, remained sound for a time. Small plants from it and from the infected field were brought together in an area already devoted to pathological study. For a short time, those from the nursery grew well, but those from the field did not. After several months, we planted a new plot, using apparently sound plants, but it failed completely.

The services of a really excellent force of plant pathologists were at our call, and all were immediately interested. For a considerable time none were able to locate the cause or suggest a cure. Disinfection of the soil, (which would be impracticable on a field scale, anyway) is not effective. The first apparently positive statement came, more than a year after the pathological study began, from Dr. Ocfemia, who reported that he has isolated a *Colletotrichum* from diseased *Ceratopteris,* and produced the disease by infection from his laboratory culture. We have no idea as to the source of infection of our cultures. It seems far more probable that the fungus from some other host adapted itself to the fern, than that the infection was from other *Ceratopteris.*

For the present, the only study of this fern possible at Los Baños is of the fungus. Fungus diseases usually yield to sufficient study, and it must be supposed that this one will do so. The culture of the healthy fern is remunerative enough to demand that such study be continued until it succeeds.

As a summary of our work with this fern, we can say that:

1. We have produced with *Ceratopteris* a remarkably palatable crop of at least reasonable food value. This statement as to food value is based on preliminary analysis by the chemical laboratory of the Bureau of Plant Industry, and a verbal report of such analysis by the Bureau of Science.

2. On ordinary, typical rice land, using the land for a season no longer than does rice, it yields a crop with fully three times the gross and net value of rice on the same land.

3. It is recommended for local culture on a moderate scale in any locality where lowland rice thrives in the Philippines. The

culture should be by the use of local plants. Because of the probability of infection, we do not dare to supply planting material from Los Baños.

When it became clear that any, except pathological, work on *Ceratopteris* is for the present impracticable, we turned our attention again to the common *pacó, Athyrium esculentum.* Contrary to first impressions, this can be multiplied with considerable rapidity, by means of numerous rhizomes, below the surface of the soil, which produce vigorous young plants all around each old one. These begin to produce before the age of six months, the yield increasing to the age of more than a year. During this time, care costs almost nothing. Plants set forty centimeters apart produce a solid stand, proof against the competition of most weeds. It will thrive on any soil, but is probably most vigorous where *Ceratopteris* thrives best—on rich mud. It endures standing water for considerable periods, but merely wet soil seems to be preferable.

Whole and very young fronds can be harvested, as in the case of *Ceratopteris.* But, in the case of *Athyrium,* a greater yield is obtained, with much more advantage to the plant, if harvest is deferred until half or more of the frond—the basal part—is expanded. The young tip, five to eight centimeters long, is then pinched off with the fingers, or cut off with a knife. The length of this tip must depend upon the vigor of the plant; it should contain no perceptible fiber. As the larger part of each frond remains to perform the function of the leaf, the tip of every frond can be harvested without seriously impairing the vitality of the plant. If this steady harvest be maintained, the result is a dense, uniform stand, fifty to eighty centimeters tall. To maintain this adult stand in good order, it is then necessary to go through the planting at rather frequent intervals, cutting out the moribund fronds. Our experience has not lasted long enough to fix a limit to the profitable maintenance of a planting; we have carried two "paddies" to an age of more than two years.

The uses are the same as those of *Ceratopteris*—greens and salad. As to palatability, some prefer one, some the other. My endorsement of both is that I find myself preferring whichever is at hand; and I prefer either to any other vegetable salad. The *Athyrium* has distinctly more body, and is therefore more likely to be canned successfully. Within the period of its demonstrated activity, *Ceratopteris* is more productive than adult *Athyrium.* But the continuous harvest for an indefinite

period from the latter may make it more remunerative in the long run. Our harvest of *Athyrium* has not been sufficient to provide dependable data, but seems to indicate a yield of at least two thousand pesos a year a hectare. The harvest is more expensive than that of *Ceratopteris,* but is incomparably cheaper than the collection of wild *pacó.*

Our study of *Athyrium* as a crop is hardly more than begun, but fully justifies the positive conclusion that it will be highly remunerative, and is very easy. The culture is so easy that the market demand should be satisfied entirely by cultivated material.

We have tested a considerable number of *Athyrium* species as to palatability, and have found them all good. However, none promises to rival *A. esculentum* as a crop. *A.* (*Diplaziopsis*) *javanicum* is the most succulent species, but we have been unable to "domesticate" it.

Dryopteris prolifera, growing in the same situation as *pacó,* is recognized as edible, and called *pacong calabao.* Its irregularly spreading habit makes it less amenable to culture, and it is less palatable.

One other fern, also always collected wild, comes onto the Manila market annually during the earlier rains; this is *Helminthostachys zeylanica,* locally known as *tungkod lañgit.* I had imagined that it would produce only one or two fronds a year, as is expected of *Botrychium;* but a potted specimen in our fern pit has produced seven fronds within the year. Even so, we see no prospect of its successful treatment as a crop. In savoriness, it rivals *pacó* and *Ceratopteris.*